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PHYSICS.—*Frontiers of aerodynamics.*[1] HUGH L. DRYDEN, National Bureau of Standards.

Tonight we hold the 1077th meeting of the Philosophical Society, beginning the 65th year of activity. By long-standing custom, a special meeting is set apart for the president's annual address, originally the meeting just preceding the annual meeting, but for many years now it has been deferred until the president is relieved of the cares of office. With few exceptions the presidential address has been devoted to a survey of some specialized branch of science, thus fulfilling the prophecy of Professor Henry in his first presidential address that the society should become "a means of instruction to all its members, the knowledge of each becoming, as it were, the knowledge of the whole."

I wish to continue this tradition by outlining to you the present situation on three frontiers of the science of aerodynamics. The territory of aerodynamics is bordered on the north by the great unknown land of unsolved problems of the science itself, on the east by the occupied territory of other specialized sciences such as meteorology, oceanography, hydrodynamics, heat transfer, etc., and on the west by the domain of the practical arts, the home of the engineering fraternity.

I shall perhaps devote what seems to be an undue amount of space to the northern frontier. In these days as never before, many people find it difficult to understand why any attention should be paid to a territory so cold, so barren, so uninviting, so unpromising, so useless, as that of the unknown fields of pure science. Effort expended in that direction bears no promise of immediate large dividends. Many expeditions return fruitless with their original resources expended, apparently a total loss. Others return with a collection of curiosities of no present market value. A recent critic voices his

[1] Address of the retiring president, delivered before the Philosophical Society of Washington, January 5, 1935. Publication Approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce. Received January 17, 1935.

estimate of the returns of some of these expeditions into the unknown as follows:

"Of that which is comprehensible, a high percentage is useless because it deals with pure research work which leads nowhere, or with research into problems which were settled years ago by successful designers.

"The matter of the report is scientific hokum, the manner is literary hooey."

The same critic is very enthusiastic in his support of activities on the western frontier, in what he terms *ad hoc* research as contrasted with *basic* research. In his own words:

"*Ad hoc* research may be defined as hunting for a needle in a haystack, when you do know that a needle is there, whereas basic research is just turning over haystacks on the off chance that there may be a needle or a pin or something worth picking up."

Unfortunately, when one finds the needle which is known to be present in the haystack, he painfully discovers, by the same process by which he discovered the presence of the needle, that there is a pin in the haystack and the haystack must be overturned again, and when the pin is found, behold, there must be a spike present, and so on ad infinitum. Basic research is rather the turning over of haystacks in a particular manner, painstakingly sifting the hay and listing the needles, pins, spikes, and other objects found in the haystack, so that in time it will not be necessary to turn over all of the haystack because the characteristic locations of needles, pins, spikes, etc. will be known.

One can not by ridicule or lack of appreciation detract from the value of a permanent contribution to the knowledge of humanity, or minimize the importance of the many unsuccessful attempts which are an essential part of the attainment of the goal. It is hoped that this brief review of the frontiers of aerodynamics will illustrate by precept and example how the activities on the northern frontier are essential to the welfare of the neighboring territories.

The Philosophical Society had the privilege of hearing the first reports of one of the early expeditions into the north, in a region whose resources we are beginning to appreciate.

A little more than thirty years ago, at the 581st meeting of the Philosophical Society on February 27, 1904, A. F. Zahm reported more fully than he had done at the 554th meeting about two years earlier the results of his three years' experiments on *Atmospheric friction, with special reference to aeronautics.* At the same meeting C. M. Manley spoke on the *History and present status of aeronautics,* and included a discussion of Langley's aerodrome and the accidents in launching

HUGH L. DRYDEN

President Philosophical Society of Washington

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it the preceding fall. Professor Marvin, then president of the society, was in the chair. Langley and Alexander Graham Bell were present and discussed the papers. I often wish I could have been present at that historic and memorable meeting.

In his paper Zahm stated:

"To complete the theory of the skin-friction board, two steps further remain to be taken. First, the equations of motion for a viscous fluid must be integrated to find the velocity at all points in the disturbed region about a thin material plane. Then the speed of flow must be measured at all points next the plane and at some distance away. The writer expects soon to map the stream-lines and measure the velocity. If, then, the equations can be integrated so as to give the speed as a function of the space coordinates, the computed and observed values can be directly compared. It is hoped that some one may obtain sufficiently general solutions of the equations to be of practical value, particularly for the simpler case in which the plane is indefinitely wide, in which the edge conditions are negligible."

I have never asked Dr. Zahm whether he made the attempt "to map the streamlines and measure the velocity." Probably difficulties were encountered, for only within the last few years have adequate methods of measurement been developed. From the data which will be given presently (Fig. 1) we may estimate that the thickness of the disturbed region could not have exceeded 3 inches and was probably much less at the downstream end of the longest board, which was 16 feet long. Certainly the speed was not less than 80 per cent of the speed of the free stream at points more than 0.1 inch from the surface. The completion of this part of the important program outlined by Dr. Zahm had to await the development of a technique of measuring speed very close to a surface.

The pioneer measurements were made by J. M. Burgers and B. G. van der Hegge Zijnen at Delft in 1924 with the aid of a hot wire anemometer. Measurements of the local speed were made at several hundred points for five speeds of the free air stream. Fortunately, it is possible to utilize the methods of dimensional analysis to devise a method of plotting which gives one a general view of the results. The speed V at any point, whose coordinates are x and y with respect to rectangular axes whose origin is at the front edge of the plate, is a function of the speed V_0 of the air stream, of the density ρ and viscosity μ of the air, and of x and y. By dimensional reasoning we find that

$$\frac{V}{V_0} = \phi\left(\frac{V_0 x \rho}{\mu}, \frac{V_0 y \rho}{\mu}\right)$$

Therefore with $V_0x\rho/\mu$ and $V_0y\rho/\mu$ as abscissa and ordinate, respectively, we may plot contours along which V/V_0 is constant and equal to assigned values. The resulting diagram is shown in Fig. 1, the ordinates being magnified 200 times with respect to the abscissae. In more familiar terms, if the speed V_0 is 20 feet per second, the numbers along the abscissae are in tens of inches; each square along the ordinates is one-hundredth of an inch; and the contour lines con-

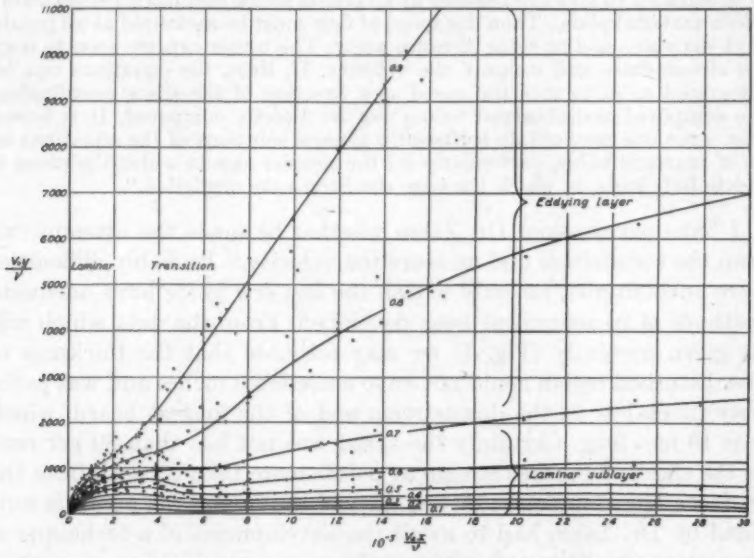


Fig. 1.—Speed distribution near skin-friction plate, van der Hegge Zijnen's measurements. See text for explanation of symbols, except ν which is the kinematic viscosity. $\nu = \mu/\rho$.

nect points whose speeds are 18, 16, 14, 12, 10, 8, 6, 4, and 2 feet per second.

The contour for $V/V_0 = 1$ is not shown, since V approaches V_0 asymptotically. The limited region with an ill-defined outer boundary within which the influence of the plate is felt is the so-called *boundary layer*. It becomes a more real thing when measurements have been made within it and its inner structure has been examined.

Near the upstream edge the contours are approximately parabolic in shape and correspond fairly well to a solution of the Prandtl boundary-layer equations given by Blasius in 1908. The flow in this region is designated *laminar flow*.

From a $V_0x\rho/\mu$ of about 300,000 to about 500,000, a new phenom-

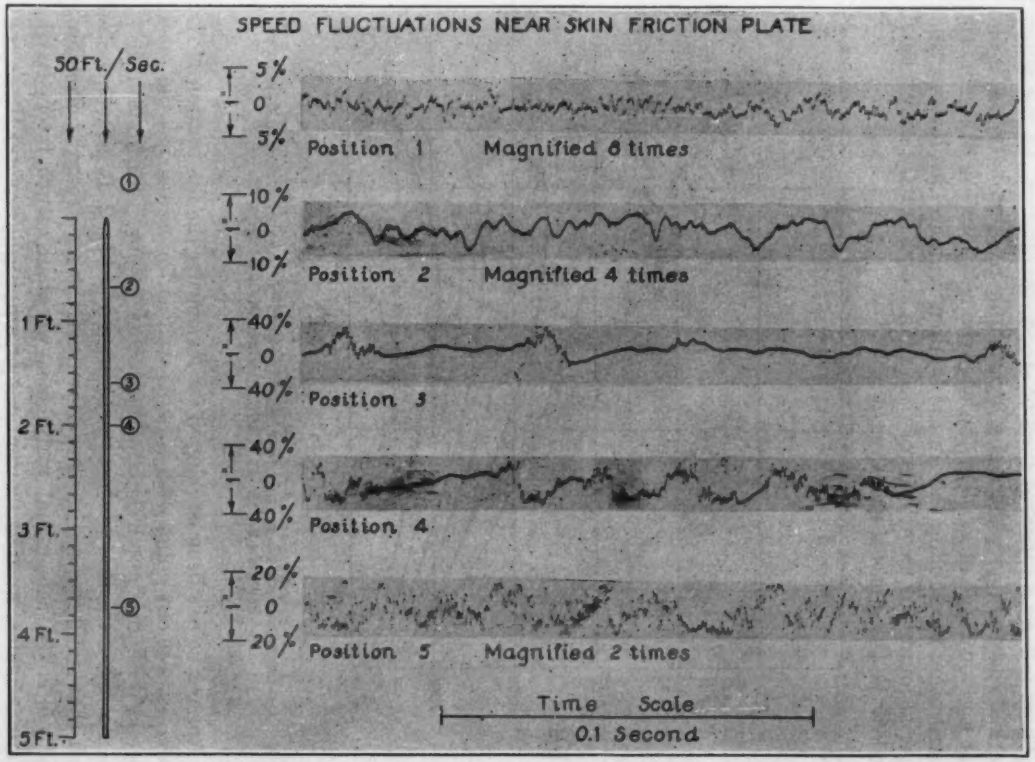


Fig. 2.—Oscillograph records of fluctuations of speed at several points near skin-friction plate.

enon arises, the air close to the surface being accelerated instead of retarded. This region is termed the *transition region.*

There follows a different type of speed distribution. In the region marked *eddying layer,* there is a logarithmic relation between V and y at a given value of x. Near the wall the relations are different, the distribution resembling that in the laminar region. This *laminar sublayer* accounts for two-thirds of the fall in speed but for only a small part of the thickness of the layer.

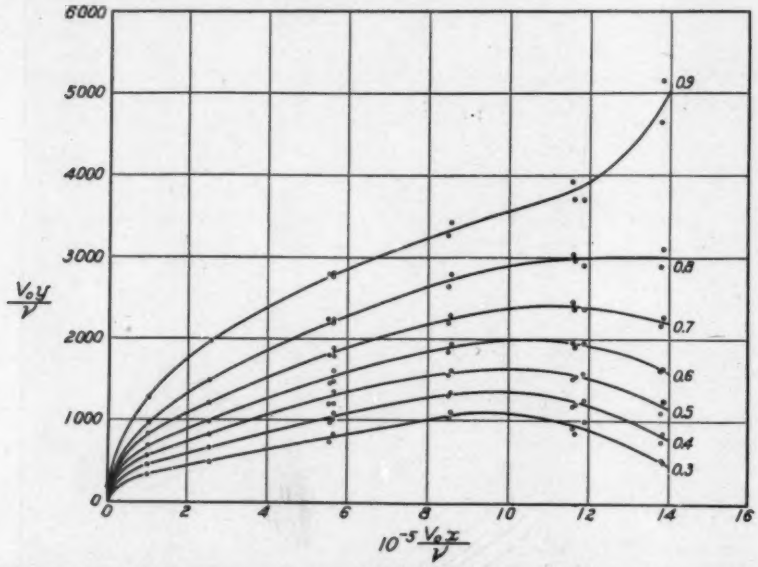


Fig. 3.—Distribution of speed near skin-friction plate, turbulence 0.5 percent. Measurements at National Bureau of Standards.

Apparatus has been developed for measuring the fluctuation of the speed at a given point with time as well as for measuring the mean speed. With this apparatus we may obtain some information as to the nature of the flow of the type indicated in Fig. 2. It may be noted first that small fluctuations are present in the air stream approaching the plate. To this initial turbulence we shall return later. In the laminar region we find fluctuations of amplitude several times that in the approaching stream but much slower. In the eddying region the fluctuations are very rapid. The transition, which appears to be gradual in the measurements of mean speed, is actually a very sudden one. There is an intermittent change from laminar to eddying flow,

occurring at infrequent intervals near the beginning of the transition region and at more and more frequent intervals as the end of the transition region is approached. The phenomenon is identical with that long known to occur in the flow of water in pipes, and frequently exhibited by the aid of streams of dye. The wavering of the color

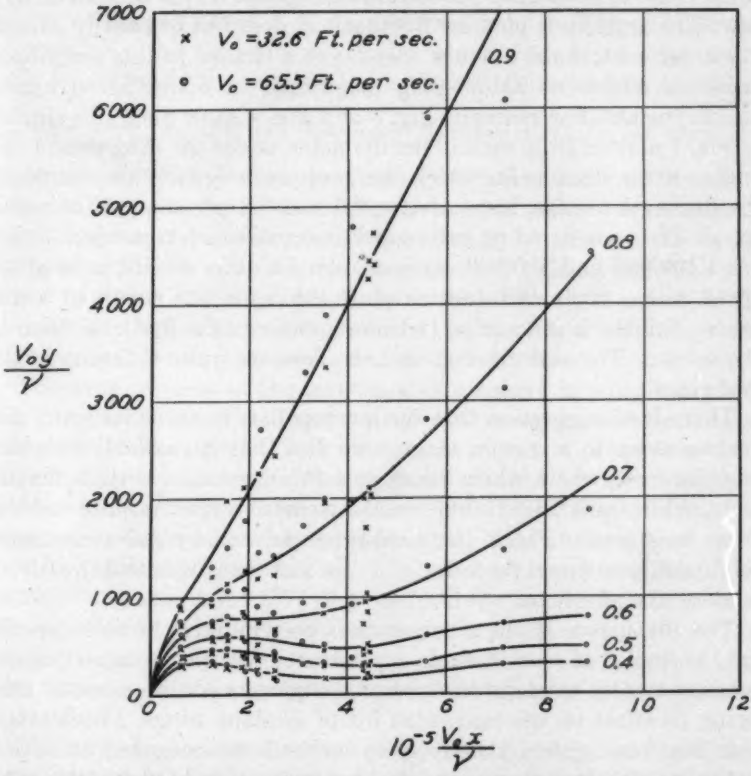


Fig. 4.—Distribution of speed near skin-friction plate, turbulence 3.0 percent. Measurements at National Bureau of Standards.

bands in the laminar flow, the sudden diffusion through the pipe when the flow becomes eddying, the wandering of the point of transition, all are now familiar but not understood.

The true distinction between laminar and eddying flow is not based on the presence or absence of fluctuations. In eddying flow, the fluctuations are of such a nature that there is a net transfer of momentum by the motion of small masses of fluid in addition to the molecular

transfer. In laminar flow, this additional net transfer of momentum does not occur.

It has been found experimentally that the transition from laminar to eddying flow is profoundly affected by the magnitude of the initial *turbulence*, the name given to the small fluctuations of frequencies of the order of 20 to 1000 per second superposed on the desired steady flow. The amplitude of these fluctuations does not ordinarily exceed a few per cent of the average speed, yet a change in this amplitude produces effects of astonishing magnitude in many aerodynamic measurements. For example, Fig. 3 and Fig. 4 show diagrams similar to Fig. 1 plotted from measurements made under the direction of the author in air streams for which the root-mean-square amplitude of the fluctuations was, respectively, 0.5 and 3.0 per cent of the mean speed. The corresponding values of $V_0 x\rho/\mu$ at which transition occurs are 1,100,000 and 100,000, respectively. In other words, at a given speed with a given skin-friction plate the transition occurs at a distance from the leading edge 11 times greater in the first case than in the second. The skin friction and the flow are quite different in the two cases.

There is no suggestion that the laminar flow is stable for small disturbances up to a certain magnitude and that it suddenly becomes eddying everywhere when the disturbance exceeds a certain magnitude. While for a fixed turbulence the transition itself is quite sudden, as we have seen in Fig. 2, there is a progressive and regular functional relationship between the value of $V_0 x\rho/\mu$ at transition and the turbulence of the airstream.

The turbulence of the airstream has been found to be an independent variable of considerable importance in many aerodynamic measurements, chief interest among engineers at the present time being its effect on the maximum lift of airplane wings. Much attention has been given, therefore, to methods of assigning numerical values to the turbulence and to the correlation between the aerodynamic measurements and the numerically assigned values.

It is possible to measure directly the root-mean-square fluctuation of the speed at any point with time by means of a special form of hot-wire anemometer, with a wire of small diameter (0.017 mm), an amplifier, an electrical network to compensate for the lag of the wire, and an alternating current milliammeter. The speed fluctuation is converted into an alternating current whose intensity is measured. The ratio of the root-mean-square fluctuation to the mean speed is defined as the numerical value of the turbulence. The ratio is usually stated as a percentage.

The equipment required for the hot wire measurement is rather cumbersome and requires considerable care and skill on the part of the operator. A more convenient method is to utilize some aerodynamic measurement which is sensitive to turbulence. The measurement most generally used is that of the resistance of a sphere. If one measures the resistance R of a sphere of diameter D in an airstream of speed V_0, the air being of density ρ and viscosity μ, the results may be conveniently expressed as a plot of the resistance coefficient $C_D = \frac{R}{\frac{1}{2}\rho V_0^2 \frac{\pi}{4} D^2}$ against the Reynolds Number $V_0 D\rho/\mu$. At very low Reynolds Numbers C_D is approximately constant and equal to about 0.5. At Reynolds Numbers within a range of values dependent on the turbulence the coefficient decreases rapidly to values in the neighborhood of 0.1. To obtain a definite numerical value it has been proposed to define the Reynolds Number for which C_D is equal to the average of these two values, namely 0.3, as the *critical* Reynolds Number and to use it as a measure of the turbulence.

The measurement of the resistance of a sphere in wind tunnels of varying size is somewhat inconvenient and in any case there is some complication because of the forces on the supports. Therefore there has recently been introduced a pressure-sphere, in which a simpler measurement of differential pressure is utilized. The difference in pressure Δp between an impact hole at the front of the sphere and a hole (or preferably a number of holes) on the downstream side at an azimuth angle of about 157½ degrees from the impact hole is divided by the velocity pressure $q = \frac{1}{2}\rho V_0^2$ to give a pressure coefficient. The critical Reynolds Number is defined as that for which $\Delta p/q = 1.22$. The values obtained are approximately the same as those for which $C_D = 0.3$.

The first comparisons between these methods of measuring turbulence showed extremely good correlation, but as more information became available it became apparent that the critical Reynolds Number of a sphere as defined above depends on the size of the sphere and on other properties of the fluctuations as well as on the root-mean-square amplitude. In some recent work on this problem at the National Bureau of Standards, artificial turbulence was introduced in an airstream by a series of geometrically similar wire screens. For each screen, identified by the mesh distance, different values of the root-mean-square amplitude of the fluctuations were obtained by working at different distances. To avoid variations of mean speed and of turbulence across the stream, the distance had to be greater than 70 times the diameter of the screen wire. The relation between the criti-

cal Reynolds Number of a 5-inch sphere and the hot-wire value of the turbulence for the several screens is shown in Fig. 5. Measurements on a larger sphere show that the correlation is a function of the ratio between the mesh distance and the sphere diameter. It thus

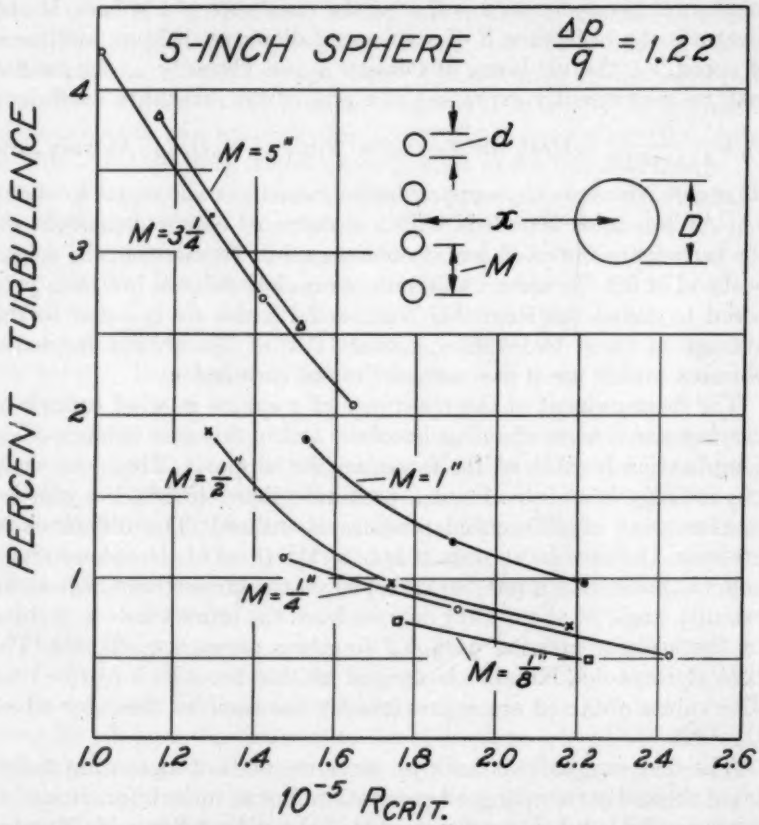


Fig. 5.—Critical Reynolds Number for pressure sphere as a function of root-mean-square fluctuation of speed. Measurements behind geometrically similar wire screens of varying mesh distance M. Square-mesh screens were used.

appears that the wire screens introduce some characteristic pattern (not that of the screen wires which disappears at a distance of 70 wire-diameters) or average size of eddy in the turbulence which affects the flow around a sphere.

Recently Dr. Schubauer at the National Bureau of Standards has introduced a third method of measuring turbulence which promises

to be quite useful. He found that the temperature distribution at some distance downstream from a hot wire of small diameter was a function of the turbulence. The dynamic wake of the small wire disappears at short distances, the wire acting substantially as a line source of heat in a uniform stream. The thermal wake widens at a rate dependent on the turbulence, and the width of the thermal wake between points where the temperature rise is one-half the maximum temperature rise furnishes a suitable measure of the turbulence. The correlation with hot wire measurements is very good and the equipment required is relatively simple, a thermocouple and sensitive galvanometer being the essential elements.

It is perhaps obvious that a completely satisfactory method of measuring turbulence can not be developed until we understand more completely the mechanism of the transition from laminar to eddying flow and the influence of this transition on the flow, pressure distribution, and force acting on bodies immersed in a fluid stream.

We have already noted the effect of the transition on the skin friction. Another basic effect is that on the process of separation. When, for example, air flows around a cylinder, there is a thin well-defined boundary layer only over the forward part. The flow separates from the surface somewhat forward of the median plane, the air near the surface in the region just downstream from the separation zone moving forward in a direction opposite to that of the main stream. Separation occurs when the pressure increases in the downstream direction and the essential features can be derived from the boundary layer equations of Prandtl. The retarding effect of the adverse pressure gradient finally predominates over the frictional transfer of momentum from the faster moving particles. The reversal of flow, on account of the consequent accumulation of fluid, separates the flow from the surface.

If transition to eddying flow in the boundary layer occurs before the separation zone for laminar flow is reached, the process of separation is delayed to a greater azimuthal angle. The eddying flow promotes a more thorough mixing and transfers momentum more readily to the fluid layers near the surface of the cylinder. The behavior of the resistance coefficient or pressure coefficient of a sphere is to be attributed to the effect of the transition on the process of separation and the influence of turbulence on the coefficients is to be attributed to the influence of turbulence on the transition.

The boundary layer at the front of a cylinder differs from that on the skin-friction plate because of the presence of a pressure gradient

in the direction of flow which arises as a result of the increasing speed. This pressure gradient acts to accelerate the flow within the boundary layer and to retard the increase in thickness of the layer. The presence of a small pressure gradient in the wind tunnel airstream is responsible for the supposed discrepancies between experiment and theory in some experiments on skin-friction plates. The theoretical equations show that small pressure gradients have effects much larger than one might suppose.

The existence of an accelerating pressure gradient also affects the transition, delaying it to higher values of $V_0 x\rho/\mu$. The few experiments available indicate that the transition is controlled by the value of $V_0\delta\rho/\mu$ where δ is a suitably defined *thickness* of the boundary layer, for example $\int_0^\infty (1-V/V_0)dy$. Much more work remains to be done to verify this hypothesis and to study the influence of other factors, such as the curvature of the flow, temperature gradients, etc., on the transition.

The equations of Prandtl describing the flow in a boundary layer are adequate to account for the experimental results so long as the flow is laminar. The unsolved problems of the laminar boundary layer are principally mathematical in character. In the case of eddying flow, even the basic equations are unknown, at least in usable form. Some suppose that the eddying flow represents an unsteady motion which satisfies the fundamental equations of Stokes-Navier for a viscous fluid. Others consider it necessary to introduce additional hypotheses. Notable advances have been made by combining theoretical considerations with empirical results obtained by experiment.

All of these methods begin from the hypothesis of Osborne Reynolds that the flow could be regarded as consisting of a mean flow and a superposed fluctuating motion which could be clearly distinguished. The equations of the mean motion are identical with the equations of Stokes except for certain terms depending on the so-called eddy stresses. The eddy shearing stresses for example are $\rho\overline{u'v'}$, $\rho\overline{u'w'}$, and $\rho\overline{v'w'}$ where the bar denotes mean value, ρ is the density, u', v', w' are the components of the fluctuations at a point. Obviously these stresses are zero unless there is a correlation between the several components.

The eddy shearing stress is analogous to the viscous shearing stress, the eddy fluctuations being analogous to molecular fluctuations. The effect of molecular motions appears in the smoothed equations of motion as the viscosity coefficient. While the viscosity depends only on the temperature, the eddy stresses vary from point to point, being unknown functions of the mean flow. Reynolds general theory

gives no information about the fluctuations themselves, showing only the effect of known fluctuations on the mean motion.

One hypothesis as to the relation between the fluctuations and the mean motion which has been often used is implied in the introduction of the eddy viscosity, a quantity which relates the eddy shearing stresses to the mean motion in the same way that the viscosity relates the viscous shearing stresses to the mean motion. This procedure implies certain relations between the components of the fluctuations at a point, but the eddy viscosity may still vary from point to point. Although a formal simplification results, some assumption must still be made as to the variation of the eddy viscosity throughout the flow.

The analogy between the molecular motions and the eddy motions was pushed somewhat further by Prandtl in the introduction of the mixing length, which plays the same part in the eddy motions as the mean free path in the molecular motions. The isolation of small fluid masses and the mixing length itself actually exist only in a statistical sense. Prandtl's reasoning led to the result that the eddy viscosity was equal to ρl^2 times a function of the mean motion which for a parallel flow reduces to the transverse velocity gradient. The variation of the eddy viscosity from place to place is replaced by a variation of the mixing length l from place to place, which at first sight offers no advantage. But experiment shows that at large Reynolds Numbers the mixing length is practically independent of the speed and simple assumptions as to the spatial distribution give reasonably accurate results.

A further step was taken by von Kármán, who assumed that in the eddying motion the fluctuations at all points were similar, differing only in the linear scale and in the intensity of the fluctuations. This assumption led to an expression for the mixing length in terms of the mean flow and a universal constant. The consequences of the assumption have been worked out rigidly only for the case of parallel flow. The formulae for the skin-friction and for the velocity distribution obtained from Kármán's theory are in remarkably good agreement with experiment.

Until comparatively recently the only experimental information available on the characteristics of eddying flow consisted of measurements of mean values of speeds, pressures, or forces. A beginning has now been made on the experimental study of the fluctuations themselves by several independent methods. The use of the hot-wire anemometer has been studied at Delft, Göttingen, Teddington, California Institute of Technology, and at the National Bureau of Stand-

ards. Fage has applied the ultramicroscope with rotating objective. Townend has developed a technique using small sparks which give *hot-spots* that are rendered visible by the Schlieren method. Lindvall utilized the effect of the wind on a glow discharge between two electrodes. It seems certain that within a few years a considerable amount of information will be available to serve as a guide to the further development of the theory of eddying flow.

The expedition into the unknown begun by Dr. Zahm thirty years ago has thus been followed by others into the same regions, and we feel that we know something more about the territory. New interrelations have been discovered, and we feel that we have the key to the general geographical structure of the country beyond. It is astounding that the study of such a simple problem as the flow of air past a skin-friction plate should lead so far. But as the germ cell contains within itself the possibility of development into a rather intricate structure, so a single problem in aerodynamics contains within itself the possibility of answering many aerodynamic problems.

The account which has been given of studies in this particular section of the northern frontier could be repeated for other sections. One might, for example, describe the further development of another field of investigation to which Dr. Zahm contributed, the behavior of air at speeds near and above the speed of sound. Or one might describe the explorations, which are practically just beginning, on accelerated and unsteady motion, such as is associated, for example, with the pitching of an airplane wing. But we must now turn to the frontier on the east, bordering on the neighboring sciences.

Aerodynamics and hydrodynamics occupy much territory in common and are often regarded as essentially the same. It is true that the language and habits of thought are in large measure identical, but in the details of experimental technique there is sufficient difference that the experimenter in one field is not at home in the other without a season of apprenticeship. The theoretical workers intermingle more freely. Then too there are certain more or less isolated regions in both sciences, for example, the field of compressibility effects in aerodynamics and the fields of free-surface phenomena and of cavitation in hydrodynamics which are distinctive in character.

The indebtedness of the younger science, aerodynamics, to the older is very great. In water, events occur in slower tempo, a given flow-pattern occurring at about one-thirteenth the speed which would be necessary in air. The internal motions of water are readily made visible by small amounts of dye and the eye can in many cases readily

follow the motion. In air, on the other hand, it is necessary to use large volumes of smoke, to take photographs with a high speed motion-picture camera, and to view the pictures at a much reduced speed, if one wishes to observe the motion at reasonably large values of the Reynolds Number. Thus aerodynamics owes not only the underlying theoretical background, but also many of its mental pictures and experimental methods to hydrodynamics.

The benefits have not been altogether one-sided. The circulation theory of lift developed from the stimulus of an aerodynamic problem has found repeated application in hydrodynamic problems relating to hydrofoils, pump and turbine blades, etc. The boundary-layer theory is finding fruitful application in hydrodynamics as well as in aerodynamics. All that has been said about the transition from laminar to eddying flow and the effect of turbulence can be carried over word for word to the flow of water. Even the experimental techniques developed for studying fluctuations in eddying motion in air are beginning to be adapted to similar studies in water.

The sciences of meteorology and oceanography are coming under the influence of aerodynamic ways of thinking. I shall give only one or two illustrations. Atmospheric winds near the Rock of Gibraltar have been found hazardous to aircraft, especially when the wind blows from certain quarters. It occurred to someone to make a model of the rock, put it in a wind tunnel, and explore the flow in detail for several wind directions. The general features were checked by observations in natural winds at the full-scale rock.

About two years ago C. G. Rossby, Professor of Meteorology at the Massachusetts Institute of Technology, published a paper entitled *A generalization of the theory of the mixing length with applications to atmospheric and oceanic turbulence.* The title is self-explanatory. In this paper we find reference to boundary-layers from a 1000 feet to several miles in thickness. In a paper soon to be published by A. M. Kuethe of the Daniel Guggenheim Airship Institute at Akron, we may read of measurements of speed fluctuations within such a boundary-layer.

At the Fourth International Congress of Applied Mechanics, L. Prandtl presented a paper on the application of the laws of turbulent friction to atmospheric phenomena. He treated a number of special problems as well as the problem of the general atmospheric circulation on a rotating earth. Schlichting gave a theory of the stability of the laminar flow in a heated boundary layer and compared the results with measurements by Reichardt at Göttingen. These measurements

were made with a view to their application in meteorological problems.

The theory of heat transfer in forced convection has undergone a veritable revolution by the introduction of the boundary layer as a substitute for the hypothetical *film*. With the introduction of the concepts of laminar and eddying flow, and of transition as dependent on initial turbulence, many apparent contradictions have been explained. As indicated by Pohlhausen and Latzko, we can now proceed several steps beyond the convenient assumption of uniform mass flow of the fluid in studying the theory of forced convection. Thermal boundary layers are recognized as well as dynamic boundary layers. There is a mixing length involved in the transfer of heat as well as in the transfer of momentum and the two may or may not be the same. We introduce an eddy conductivity as well as an eddy viscosity and inquire as to their relationship.

The analogy between heat-transfer and skin-friction has been found very useful. Closer examination is revealing that the analogy has been perhaps pushed too far, ignoring the fact that pressure gradients affect the dynamic but not the thermal boundary layer and that momentum is a vector quantity whereas heat energy is a scalar. This interchange of information is proving beneficial to both sciences, the heat-transfer measurements throwing considerable light on the characteristics of eddying motion.

The study of evaporation and of diffusion has been facilitated by the introduction of the concepts of the laminar sub-layer and of mixing length. The experimental study of the relation between the mixing lengths involved in the transport of momentum, heat, water-vapor, solid particles, etc., promises to throw light on the mechanism of all.

Such are some of the contacts on the eastern frontier. While I do not claim that aerodynamics has always been benefactor and never beneficiary, I do think it is clear that the extension of the knowledge of how air moves near solid bodies immediately makes possible corresponding advances in the neighboring sciences.

We turn now to the western frontier, a region more familiar perhaps than those which we have been considering. Aerodynamics, of course, became of practical importance in the world with the development of aviation, and by far the larger share of aerodynamic research looks to aeronautics for its support. Until very recently, this territory was the only one with which there was efficient inter-communication. However, an adequate discussion of the interchange between aeronautics and aerodynamics, which after all *are* different fields of en-

deavor, would require much more space than can be given here and is perhaps superfluous for the purposes of this paper. The borderland here has long since ceased to be a frontier.

We shall accordingly turn to those regions which are still frontier in character, the first being the borderland between aerodynamics and the practical art of ventilation. The principal aerodynamic problems of ventilation may be briefly stated as (1) the design of fans, (2) the reduction of friction losses in ducts, and (3) the distribution of air from a small number of inlets throughout a large space. The design of fans involves the same fundamental principles as the design of airplane propellers, but a good airplane propeller is not a good fan. Nevertheless, in certain applications, such as in cooling towers used for cooling the water from condensers of steam-turbines, where large quantities of air are required to be delivered against comparatively small pressures, the simplicity and low initial cost of an inexpensive propeller mounted directly on the shaft of an electric motor led to several installations about five years ago. Soon after, aerodynamical principles were applied by one of the manufacturers, leading to a fan with comparatively large hub (one-third to one-half the diameter of of the fan) and with blades whose pitch increases toward the hub, with a very considerable improvement in efficiency. Very recently, Professor Marks and his colleagues at the Harvard Engineering School, have shown that an axial flow fan, with a diffusor and guide vanes, can be constructed to have an efficiency of 80 per cent.

There has also been much interest in the use of fans of this type for forced-draft installations, and for mine ventilation. Multi-stage fan wheels, with alternate rotating and stationary blades, have been proposed. There are, of course, disadvantages as well as advantages. The noise is much greater than for slower speed, multi-blade fans and the power-characteristic curve has some undesirable features. However, the application of aerodynamical knowledge to fan design is only in its infancy.

Information on air friction is immediately applicable in the design of ventilating ducts. However, the exigencies encountered in actual installations lead to many installations where the principal losses are due to obstructions or bends rather than to friction. When air flows around the usual pipe-bend, secondary motions are produced by the action of centrifugal force which destroy the approximately uniform flow. Large-scale turbulence is produced, with large energy losses associated with the dissipation of energy of this turbulence into heat. It has been found that these secondary motions may be largely elimi-

nated by using guide vanes arranged as a series of curved parallel blades which divide the airstream into a number of smaller streams which are separately guided around the bend. I believe these guide vanes were first developed at Göttingen in connection with the return-circuit wind tunnel, a set being installed at each bend. They have since found application not only in wind tunnel design, but in the design of ventilating ducts for large electrical generators. The theory of the action of these vanes is well worked out. The possibilities of their application have not been exhausted.

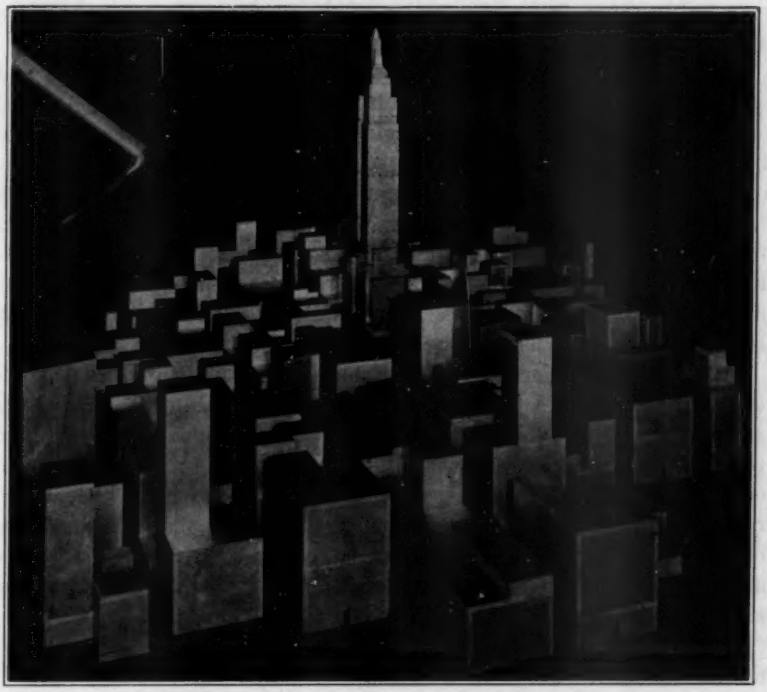
As an illustration of the reduction of losses due to obstructions, the ventilating ducts of the Holland vehicular tunnel may be mentioned. The exhaust duct is formed by the use of a false ceiling suspended from the top of the tunnel. In the original design the ceiling was to be suspended by cylindrical rods. A simple calculation showed that the resulting losses could be greatly minimized by a partial streamlining of the obstructions, accomplished by substituting flat strips edge on to the airstream for the cylinders.

The study of the distribution of air from fresh-air inlets is a virgin field. The investigation of turbulent mixing of jets by Tollmien and others should find immediate application.

Another frontier field is the application of aerodynamics to the design of windmills. Betz in Germany has taken the lead in the study of windmill wheels of few blades suitable for driving electric generators with only moderate gear ratios between the generator and windmill-wheel. His studies have illustrated the possibilities of theoretical computation of the performance and the value of wind-tunnel tests on models as a guide to further development. Two unconventional types, the Savonius rotor and the Flettner rotor, have received some study. In this field, aerodynamics has served to restrain somewhat the expectations of those enthusiasts who feel that because the wind is free, power from the wind should likewise be free. Simple principles show that the structure required to secure reasonable amounts of power from the wind is comparatively large. Initial cost, depreciation, and insurance against damage in high winds must receive careful consideration.

A field to which we have devoted some attention at the National Bureau of Standards is that of determining the wind pressure exerted on structures in wind storms. In the design of tall buildings, radio masts, water towers, chimneys, and similar structures, the allowance to be made for wind pressure is a matter of serious concern, first, in relation to the safety of the structure, and second, in relation to its

cost. To obtain information on wind pressure from observations on a building in a natural wind would require years of measurement and a statistical study of the results. The data so obtained would be limited to buildings of similar shape with a similar exposure. The only practicable procedure is to utilize the long series of observations of the Weather Bureau to forecast the probability of the occurrence of winds



6.—Models of Empire State Building and surrounding structures for wind-tunnel measurements.

of specified speed. To obtain the pressure on the building, the relation between the pressure and the speed must be known. This relation may be determined by experiments on models in wind tunnels or by observations in natural winds. Each method has advantages and disadvantages. The principles of aerodynamics are invaluable in the interpretation of experiments by either method to avoid erroneous conclusions.

The use of both methods is illustrated in the publications of the

Bureau.[2] The wind-tunnel measurements on the model of the Empire State Building were undertaken with the expectation that measurements in natural winds would ultimately be made on the actual building for purposes of comparison. Completion of the project has been delayed by matters beyond our control. To illustrate the extent to which model experiments may be carried, there is shown in Fig. 6 a photograph of the model in the 10-foot wind tunnel with a crude but reasonably accurate representation of the territory for several blocks around. The scale is 1 to 250, the model being 5 feet high.

The results of these experiments and similar experiments abroad are slowly finding their way into building codes and in handbooks on design. The results are even having an influence in the design of houses, barns, and other farm structures as agricultural engineers recommend and insurance companies insist that houses be anchored to foundations, and that roofs be securely fastened to side walls to avoid failure as a result of suction and uplift produced by the wind. Perhaps more surprising is that at least one structure, the airship hangar at Akron, Ohio, has been especially designed to reduce the wind load, *streamlined* if you wish, on the basis of wind-tunnel tests.

As the final frontier region to be discussed, we come to the application of aerodynamical principles to the streamlining of automobiles and trains. When an automobile is driven along a level road, the power developed by the burning of the fuel is used in part to overcome the friction of the gears and bearings and of the tires on the road. The remainder of the power is used to overcome the resistance of the air. At speeds of 35 or 40 miles per hour the rolling resistance and air resistance are approximately equal and at higher speeds the air resistance becomes of the greatest importance.

If the air resistance of an automobile were due solely to air friction, the air resistance would be less than one-tenth that actually present in a typical modern automobile. It is not feasible to reduce the resistance of an actual automobile to this amount for practical reasons, but considerable improvement can be made. Halving the resistance is easily possible.

The possibility of improved fuel economy or higher speed through streamlining has been known for 10 years or more, and several experimental cars have been constructed. None of these cars has been commercially successful, and the so-called streamlining of present-day cars is essentially only a talking point. The accomplishments are trivial in comparison with the reduction that is easily possible. The

[2] Scientific Paper 523, Research Papers 221, 301, 545 and 637.

reason for the delay in introducing truly streamlined cars lies in the repugnance of the public to radical changes in appearance. Attempts are being made by manufacturers to make a gradual transition.

I do not wish to give the impression that there are no engineering problems involved in the change. There are many, but their discussion is out of place here. Their solution is in sight, if not already accomplished by some of the manufacturers.

The railroad groups are also much interested in streamlining. The new streamlined trains, which really owe much of their advantage to the reduction in weight made possible by the use of new materials and new methods of construction, have caught the public fancy. An experiment, which will be of more significance from the standpoint of streamlining alone, is the construction of a streamlined steam locomotive by one of the large manufacturers on the basis of wind-tunnel experiments.

In 1933, the National Bureau of Standards constructed for the Century of Progress Exposition in Chicago a small exhibition wind tunnel, in which were placed two models, one conventional and one streamlined, designed and constructed by W. H. Boyd of the aerodynamics section. Visitors were able to operate the wind tunnel and observe the very great difference in the air resistance of the two models. This exhibit aroused considerable interest and my colleague, R. H. Heald, has investigated not only the head-on air-resistance, but also other aerodynamic characteristics in side-winds. Mr. Heald has also made some studies of methods of representing the ground effect. These studies[3] illustrate the application of the experimental methods of aerodynamics to the streamlining problem.

In the application of aerodynamic methods to aeronautics, ventilation, windmill design, wind-pressure measurements, and streamlining, the contribution of the results obtained from basic research in aerodynamics may not be apparent to the casual observer. A little reflection, however, will show that the discovery, for example, of the very considerable effect of initial turbulence on many aerodynamic measurements must modify both the experimental procedure and the interpretation of the results. Similarly, with other advances in our knowledge of how air flows. Of course, engineers do not stop building airplanes, buildings, or automobiles until the new procedures are developed. The next generation of engineers will take the information which now seems new and use it, forgetting its origin. The present

[3] Research Papers 591, 748, and 749.

generation may continue to feel that basic research is useless, since it does not quickly answer their immediate problems.

And so we end the 1077th meeting. Thirty years from now, at the 1573rd meeting, perhaps someone will again review these frontiers.

BOTANY.—*New species and varieties of* Sedum *from China and Tibet.*[1] N. FRÖDERSTRÖM, Stockholm. (Communicated by E. P. KILLIP.)

The United States National Museum recently submitted to me a number of specimens of *Sedum* from China and Tibet, several of which prove to represent undescribed species and varieties. Most of these novelties were collected by Dr. Joseph F. Rock on his expeditions to the interior of China for the National Geographic Society and the Department of Agriculture.

Sedum aizoon L. var. **obovatifolium** Fröd., var. nov.

Kiangsi Province, Lu Shan; *A. N. Steward* 2602, July 20, 1922. (U. S. Nat. Herb. 1,345,868, type).

Planta robusta, 15–20 cm longa. Folia caulina confertim alterna, obovata, crebre dentata, obtusa, 25–35 mm longa. Inflorescentia densa, multiflora, lata, circ. 1.5×3.5 cm.

Probably but a stout local form of var. *latifolium Max.*, with exceedingly broad leaves. It seems to be nearest to a specimen from the Province of Kwei-chau, near Tschingdshen, about 1200 meters attitude (*Handel-Mzazetti* 10498 June 1917, Herb. Vienna and Fröderström), but the leaves of that specimen are more spathulate-ovate.

Sedum concarpum Fröd., sp. nov.

Yunnan, Likiang, China, alpine meadows, *Rock* 5434, 1922. (type in my herbarium; duplicate in U. S. Nat. Herb., no. 1,512,062).

Planta perennis, glabra, inferne decumbens et radicans, aphylla, in parte media rosulam foliorum et caulem floriferum, erectum, 8–9 cm longum, edens. Specimen nondum florens suberectum, multicaule, apice confertim foliosum. Folia caulium sterilium longe petiolata, fere orbicularia, apice obtusa et mamillata, basi breviter calcarata, 5–25 mm longa. Folia caulis floriferi subpetiolata, obovata, 5–10 mm longa. Inflorescentia (unius speciminis) dense corymbosa, involucrata. Flores anisopentameri, breviter (3–4 mm) pedicellati; bracteae foliis supremis similes. Sepala basi non producta, oblanceolata, prope basin leviter dilatata, apice obtusa vel subacuta, mamillata, aequalia, circ. 5 mm longa. Petala late lanceolata, sutura basali concreta, apice recurva (mitellata), 7–8 mm longa, lutea; stamina interpetala 5.5–6 mm longa, stamina epipetala circ. 2 mm supra basin inserta; antherae subovato-reniformes, circ. 1 mm longae. Squamae nect. late lineari-spathulatae, apice obtusae, circ. 1.1×0.4 mm crassae, in sicco rubrae. Carpella fere erecta, *e basi circ. 3 mm connata*, non gibbosa, satis longistyla, 5–6 mm longa;

[1] Received January 17, 1934.

folliculi 4–6–seminati, placentis rite ligamentosis. Semina subovoidea, breviter funiculata, glabra, circ. 1×0.4 mm.

Species distincta, ad *S. chauveaudi* Hamet et quodammodo ad *S. leucocarpum* Franch. spectans, folia autem petiolata laminis suborbicularibus, sepala aequalia et carpella ad medium connata.

Sedum jupaernse Fröd., sp. nov.

Eastern Tibet, Jupar Range: among rocks on Totuch nira, north of Ba Valley, 13900 ft. *Rock* 14365, July 1926 (U. S. Nat. Herb. 1,509,461, type).

Planta perennis, glabra, monoica?: flores masculos et femineos separatim ferens (an specimen gemellum e duabus plantis dioicis compositum?). Radices plures, percrassae, perpendiculares, usque ad 25 cm longae. Caudex epigaeus pluries divisus, caespitem densum, fere orbicularem formans, basi squamis desiccatis late triangularibus obtusisque cinctus. Caules desiccati valde numerosi, graciles, caules novos fere aequantes. Caules steriles vel nondum florentes erecti vel dispersi, apice confertim foliosi, 1.5–3 cm longi. Caules floriferi numerosi, flabelliformiter dispersi, 2–4 cm longi. Folia omnia lineari-lanceolata, basi non producta, integerrima, apiculata et acuta, 3–5 mm longa. Inflorescentia conferta, pauciflora; bracteae lineares, acutae, 2–2.5 mm longae. Flores omnes pentameri, breviter pedicellati. *Flores masculi:* Sepala semioblonga, subobtusa, 1.5–2 mm longa. Petala subobovata, basi leviter contracta, apice obtusa et submucronata, circ. 2.5 mm longa, in sicco lutea; stamina omnia petalis fere dimidio breviora, 1.5–1.8 mm longa, epipetala 0.5 mm supra basin inserta; antherae late reniformes. Squamae nect. quadratae, apice profunde emarginatae, circ. 0.9×1 mm in sicco luteae. Carpella minuta, late ovata, brevistyla, sterilia, vix 1 mm longa. *Flores feminei:* Sepala ut supra. Petala late ovata, infra medium parum contracta, apice obtusa, 2.5–3 mm longa, in sicco pallide lutea; *staminodia* interpetala circ. 1 mm longa, apice obtusa, epipetala 0.5 mm supra basin inserta, deinde 0.5 mm longa, apice obtusa. Squamae nect. quadratae, apice leviter emarginatae, circ. 0.75×0.80 mm, in sicco luteae. Carpella suberecta, longitudine parum inaequalia, subovoidea, brevistyla, 2.5–3 mm longa; folliculi *1–3–seminati*, placentis rite ligamentosis. Semina solitaria subovoidea, utrinque alata, glabra, 2×0.7 mm; semina alia ovoidea, 1×0.35 mm.

Species vero peculiaris, habitu ad formas chinenses *Sedi quadrifidi Pall.* maxime spectans. Ab omnibus autem differt: flores monoici?, petala lata, stamina floris masculi petalis breviora, flores feminei staminodia ferentes et eorum carpella pauciseminata.

Sedum likiangense Fröd., sp. nov.

Yunnan, Likiang, *Rock* 4991, 1922 (U. S. Nat. Herb. 1,512,574, type).

Planta perennis, glabra, dioica. Radix simplex, gracilis, circ. 10 cm longa. Caudex epigaeus multoties divisus, densissime caespitosus, caespitem fere orbicularem, circ. 10 cm diametro, formans. Squamae basales? Caules desiccati numerosi, graciles, breves. Caules steriles vel nondum florentes stellatim dispersi, apice dense foliosi, 2–3 cm longi. Caules floriferi suberecti vel dispersi, numerosi, 2–3.5 cm longi. Folia omnia lineari-lanceolata, basi breviter calcarata, apiculata et acutissima, 4–7 mm longa. Inflorescentia uniflora vel conferte pauciflora; bracteae lineares, acutae, 3–3.5 mm longae. Flores omnes feminei, tetrameri, breviter pedicellati. Calycis fundus circ.

1 mm altus, sepala semioblongo-triangularia, acuta, 3 mm longa. Petala late oblonga, basi breviter obtuseque producta, apice obtusa, 3–4 mm longa, in sicco rubra; staminum nullum vestigium. Squamae nect. trapezoideae, latiores quam longae, apice planae et emarginatae, 0.6×0.8–1 mm, in sicco rubrae. Carpella suberecta, subovoidea, brevistyla, stylis recurvis, basi circ. 0.5 mm connata, 4–4.5 mm longa; folliculi multiseminati, centis rite ligamentosis. Semina ovoidea, utrinque alata, glabra, circ. 2×0.75 mm.

Habitu valde ad *Sedum juparense* Fröd. spectans, itaque e vicinitate *Sedi quadrifidi Pall.*, a quo tamen differt habitu caespitosissimo, foliis acutissimis et inflorescentia vulgo uniflora.

Sedum megalanthum Fröd., sp. nov.

Type sheets: ♂ S. W. Szechuan, Mt. Konka, Risonquemba, Konkaling, 3960–5335 m; cushion plant, flowers red; *Rock* 16415, June 1928. ♀ Yunnan, eastern slopes of Likiang Snow Range, Yangtze watershed, 14500–15000 ft; *Rock* 9848, 1923–24 (types in my herbarium; duplicates in U. S. Nat. Herb., nos. 1,333,815 and 1,512,070).

Co-sheets: ♂ Yunnan, Yangtze watershed, western slopes of Likiang Snow Range, 12000–13000 ft; flowers carmine red; *Rock* 4346, May–June 1922. ♂ Yunnan, between Likiang, Tungshan, Tuinaoko, and Tsilikiang, dry Yangtze drainage basin, 14500 ft; flowers red; *Rock* 9780, May 1923. ♂ Muli, S. W. Szechuan, Mt. Mitzuga, west of Muli Gomba, 3050–4875 m; rock plant, flowers purplish red; *Rock* 16596, June 1928. ♂ Muli, S. W. Szechuan, Mt. Siga, northeast of Kulu, 4770–4900 m; flowers red; *Rock* 17923, June 1929.

Planta dioica, perennis, 15–20 cm longa. Caudex robustus, erectus, supra terram brevis et latus, paulum divisus, apice squamis siccis, late triangularibus acutisque cinctus. Caules desiccati plures, nigricantes, robusti, 10–15 cm longi. Caules steriles vel nondum florentes erecti, robusti, 15–17 cm longi, apice convertim foliosi, eorum folia media spathulato-ovata, subacuta, 25–30 mm longa. Caules floriferi numerosi vel pauci, erecti vel flabellatim dispersi, satis robusti, 10-20 cm longi. Folia media et superna subpetiolata, laminis ovatis vel suborbicularibus, margine integris vel undulatis vel crenatis, apice apiculato-obtusis, 6–25 mm longa. Inflorescentia dense corymbosa, lata, 10–15–flora, foliis supremis involucrata; bracteae?; pedicelli sparse papillosi, calyce aequales vel longiores. Flores pentameri, magni. *Flores masculi:* Sepala late linearia vel lanceolata, apice obtusa, 2–2.5 mm longa. Petala pseudounguiculata, usque ad basin libera, oblanceolata vel parum latiora, integra, apice obtusa, 7–7.5 mm longa, in sicco lucide rosea. Stamina omnia fere aequilonga, petala parum superantia, epipetala circ. 2.5 mm supra basin inserta; antherae ovatoreniformes, circ. 1 mm longae. Squamae nect. rectangulares, basi parum dilatatae, apice divisae vel profunde emarginatae, circ. 1.5×0.45 mm. Carpella sterilia, brevistyla, lanceolata, 3–3.5 mm longa. *Flores feminei:* Sepala e basi dilatata lineari-lanceolata, apice subobtusa, circ. 3 mm longa. Petala basi parum dilatata, oblanceolata, apice obtusa, 5–5.5 mm longa, in sicco lutescentia; stamina nulla. Squamae nect. quadratae, crassae, apice planae et leviter emarginatae, circ. 1×1 mm. Carpella erecta, brevistyla, late lanceolata, basin versus parum attentuata, 9–10 mm longa, in sicco rubra; folliculi multiseminati, placentis rite ligamentosis. Semina subovoidea, glabra, utrinque alata, apice elongata, 1.5–2 mm longa.

Species habitu *Sedo rotundato* Hemsl. valde similis, differt autem floribus majoribus, petalis pseudounguiculatis, et staminibus alte insertis.

Sedum yunnanense var. **muliense** Fröd., var. nov.

Muli, Mt. Siga, northeast of Kulu, 4300 m; flowers purplish: *Rock* 17915, June 1929 (type in my herbarium; duplicate in U. S. Nat. Herb., no. 1,510,322).

Caules floriferi suberecti, 50–60 cm longi; folia quaternata vel superne ternata, integra vel undulata, obovata vel lanceolata, obtusa, 12–30 mm longa; inflorescentia laxe thyrsoidea, e cymulis paucifloris composita; flores masculi, 5–6-meri, petala subovata, 3 mm longa.

Ad var. *forresti* Hamet spectans, sed habitu, foliorum forma et inflorescentia satis distincta.

Sedum yunnanense Franch. var. **papillocarpum** Fröd. var. nov.

Yunnan, prope Chungtien, circ. 3600 m. *C. Schneider* 3025, Sept. 1914, (U. S. Nat. Herb., no. 776,718, type).

Planta "20–35 cm" longa, quinquecaulis; folia ternata, oblonga, dentata vel sublobata, acuta, 10–30 mm longa. Flores feminei pro specie magni, pentameri; carpella turgida, papillis altis dense instructa, stylis longis recurvisque, 5 mm longa; semina lanceolata, glabra, 1.9×0.45 mm.

Var. *forresti* Hamet proxima, folia autem ternata, carpella magna, dense papillosa, et semina lanceolata.

♀ **Sedum yunnanense** var. **rotundifolium** Fröd., var. nov.

Yunnan, Tungshan, Yangtze drainage basin, east of Likiang; flowers yellowish; *Rock* 10517, 1923 (type in my herbarium; duplicate in U. S. Nat. Herb., no. 1,512,078).

Caulis solitarius erectus, 45 cm longus; folia verisimiliter opposita, denticulata, orbicularia, obtusissima, 20–40 mm lónga et lata; inflorescentia paniculata, 13 cm. longa, e cymulis longe pedunculatis, paucifloris composita; flores feminei, 4–5-meri, carpella 3 mm longa stylis recurvis.

Between var. *henryi* Hamet and *Sedum sinicum* Diels (which is probably but a variety of *Sedum yunnanense*), but the leaves are decidedly orbicular and very blunt, and the inflorescence elongate, almost thyrsoid, as in the head species.

♀ **Sedum yunnanense** var. **strictum** Fröd., var. nov.

Muli, Mountains of Kulu, 4150 m; flowers red; *Rock* 18214, Sept. 1929 (type in my herbarium; duplicate in U. S. Nat. Herb. no. 1,510,623).

Caules stricte erecti, usque ad 30 cm longi; folia ovata vel lanceolata, sublobata, apice obtusa, inferiora circ. 10 mm longa, media 15–20 mm. superiora ignota; inflorescentia thyrsoidea, angusta, interrupta, 12 cm longa, e cymulis parvis, confertis composita, flores feminei, 5–6-meri, sepalis petalisque fere aequilongis, 1.2–1.4 mm; squamae nect. longiores quam latae; circ. 0.8×0.6 mm, apice obtusae, in sicco rubrae; carpella basi lata, turgida, stylis longis recurvisque, 3–3.5 mm longa; semina lanceolata, glabra, utrinque breviter alata, circ. 1.2×0.4 mm.

Planta unica defecta, itaque non satis dignoscenda. Ad var. *forresti* Hamet spectans, sed fortasse species distincta ob habitum et structuram floralem.

PALEOBOTANY.—*Fossil plants from the Malacatos Valley in Southern Ecuador.*[1] EDWARD W. BERRY, The Johns Hopkins University.

In my discussion of the Flora of the Loja Basin in Southern Ecuador[2] I mentioned the possible presence of late Tertiary continental deposits around the source of the Rio Catamayo in southern Ecuador near Malacatos (Valladolid) and Vilcabamba south of the Sierra Cajanuma, which separates the headwaters of the Rio Zamora, an Amazon tributary, from those of the Rio Catamayo, a Pacific stream. This suggestion was based on Wolf's early work.[3] Recently through the kindness of Professor Clodoveo Carrión of Loja I have received material from two localities in the Valley of Rio Malacatos as the Catamayo is here called, one 2 km. north and the other 1 km. south of the town of Malacatos.

The material from the former, the exact locality being along the motor road under construction between Loja and Malacatos, consists of but 4 specimens containing well preserved foliage in a fine grained silt or tuff, whitish in color with some yellowish iron stains, and of a sort which is identical with some of the lithologic facies of the plant-bearing material around Loja. Four clearly recognized species are represented. These are the terminal part of a pinnule of the fern *Goniopteris cochabambensis* Berry, a leaf of the polygonaceous genus *Ruprechtia* identical with *Ruprechtia braunii* described by Engelhardt from the Pliocene tuff at Potosí, Bolivia , a leaflet of *Cassia linearifolia* described originally from Loja by Engelhardt, and a leaflet representing a new species of *Pithecolobium* which may be described as follows:

Pithecolobium ecuadorensis n. sp.

Leaflets small, sessile, inequilateral, elongate elliptical in outline, somewhat coriaceous in texture, with entire margins. Length about 2.6 centimeters. Maximum width 10 to 11 millimeters. The tip is somewhat narrowly rounded and except for its asymmetric attitude is practically equilateral. The base is very inequilateral, being ascending on one side and truncately rounded on the other. Midvein stout and curved. Secondaries well marked; there are 6 or 7 on the concave side of the midvein and 7 or 8 on the convex

[1] Received December 10, 1934.

[2] BERRY, EDWARD W. Johns Hopkins University Studies in Geology 10: 79–134, *pl. 1–6*. 1929.

[3] WOLF, T. & RATH, G. VON. Zeit. Deutsch. Geol. Gesell. 28: 392. 1876.

side; except at the base they are regularly spaced, diverging from the midvein at angles in excess of 45 degrees and camptodrome; toward the base they are more crowded, those on the concave side being straighter and diverging at a more acute angle, those on the convex side are curved and diverge at a wider angle. The tertiaries are thin but distinct and comprise 1 or more from the midvein between adjacent secondaries connected with the latter by more or less percurrent nervilles.

This is a very characteristic form. Among previously described fossil species it is very close to *P. oxfordensis* Berry of the lower Eocene Wilcox group of southeastern North America. Among existing forms it is identical with *P. gracilliflorum* Blake of Central America, although I have not compared the fossil with all of the existing species and it may well be that there are upper Amazon species equally similar to the present fossil form, in fact there is a great similarity among the leaflets of all of the existing species.

The genus *Pithecolobium*, or *Pithecellobium* as Martius spelt it, contains over 100 existing tropical species, three-fourths of which are American where they range from the Florida Keys to northern Argentina. In recent years 14 fossil species, all American, have been described. The oldest comprise 4 forms from the lower Eocene of southeastern North America. There is an Oligocene species in the same region; Miocene species in Porto Rico, the Dominican Republic, Trinidad and Colombia; Pliocene species in Bolivia and eastern Peru; and a Pleistocene form in Trinidad.

The second locality is 1 km. south of Malacatos on the west side of an irrigation ditch known as "La toma de agua del Dr. Aguierre." The matrix is a rather dense, bluish, secondarily iron-stained clay, considerably deformed and consequently hackly, but whether due to tectonic forces or slumping can not be stated. This clay has failed to yield any traces of dicotyledonous leaves, but is packed with the pinnules of the fern *Elaphoglossum carrioni* Berry already known in abundance from several localities around Loja, and from its method of occurrence obviously a compound and not a simple fronded type. In addition there are several specimens of *Goniopteris cochabambensis* Berry and *Poacites magnus* Englehardt, the last a large Chusquea-like grass.

The present collection also contains several specimens of the fish *Carrionellus diu-mortuus* Ivor White from the nudo of Cajanuma at the southern end of the Loja Basin.

All of these forms, with the exception of the new species of *Pithecolobium* and the *Ruprechtia*, are common elements in the flora of the Loja Basin, and the deposits of these inter-montane basins in the Ecuadorian Andes are evidently all of approximately the same age.

Recently I described several occurrences of fresh water mollusks and land plants from the Cuenca Basin in Ecuador.[4] These came from near the town of Biblian in the Azogues valley, so that there is now definite evidence of the presence of similar late Tertiary continental deposits of probably fluviatile palustrine and lacustrine character, and possibly eolian as well, largely made up of volcanic ash, over a north and south distance of upwards of 150 miles. It seems very probable that similar fossiliferous deposits of approximately the same age may be expected in the other inter-Andean basins north of the Cuenca Basin.

Malacatos has a present altitude of 5187 feet which is from 1800 to 2100 ft. lower than the plant bearing outcrops in the Loja Basin and about 2800 ft. lower than the similar outcrops in the Cuenca Basin. At the present time the climate at Loja and Cuenca is arid temperate, while that at Malacatos is subtropical. In all cases the fossil plants are mesophytic tropical types and the evidence is clear that there has been a considerable amount of vertical uplift since these deposits were laid down. Whether or not their present altitude is to be ascribed to differential uplift or to deposition at originally different levels can not be stated, although it seems clear that all occurred at the same physiographic stage in the geological history of the region.

[4] BERRY, EDWARD W. This JOURNAL 24: 184–186. 1934.

ZOOLOGY.—*Life history of* Longistriata musculi, *a nematode parasitic in mice.*[1] BENJAMIN SCHWARTZ and JOSEPH E. ALICATA, Bureau of Animal Industry.

This paper contains a brief account and discussion of the life history of a trichostrongyle, *Longistriata musculi*, parasitic in the intestine of the mouse, *Mus musculus*, and readily reared to fertile maturity in white mice. In addition to the conventional account of the life history, the writers have included in this paper information on the course of infection, including a consideration of such problems as the

[1] Received December 10, 1934.

egg production, susceptibility of the host to reinfection following the apparent termination of egg production, and a discussion of the results obtained.

METHODS USED

Live infested mice were shipped to Washington, D. C., from Jeanerette, Louisiana. The feces of these animals were mixed with moist animal charcoal, and the mixture was placed on moist filter paper in covered petri dishes. The infective larvae migrated to the edges of the filter paper which were turned up at right angles to the bottom of the glass dishes. The larvae were readily detected along the edges of the filter paper, usually in clusters, adhering to the paper by their tails and waving the anterior portions of their body. By cutting off portions of the filter paper on which larvae had accumulated and placing the bits of paper in a glass dish containing a small quantity of water, the larvae could be counted readily when comparatively few were present. When large numbers of larvae were obtained in this manner they were counted by the dilution method.

In studying the development of the free-living stages, the writers isolated single eggs with the aid of a capillary pipette, and placed each egg in a drop of very dilute fecal emulsion in a small stender dish having an inside diameter of 20 mm. The dishes were kept in a moist glass chamber containing several layers of wet filter paper. The individual dishes were taken out of the moist chamber as often as necessary and examined microscopically to ascertain the progress in development.

The individual mice were kept and fed in large battery jars, a folded paper hand towel being used as bedding. The animals were fed on oats, and this was supplemented by cabbage twice a week. The feces, bedding and remnants of food particles were removed daily, and the jars were scalded with hot water and then dried. This procedure precluded the possibility of extraneous infection.

In experimental percutaneous infections, the infective larvae in a small quantity of water were placed on various portions of the skin of white mice anesthetized with ether, the mice being kept under anesthesia until the water containing the larvae had evaporated. The larvae were placed on portions of the skin from which the hair had been clipped or shaved. Larvae were introduced into the mouth in a small quantity of water with the aid of a pipette. The lungs, liver, portions of the wall of the alimentary canal and other organs were examined post mortem for larvae with the aid of the Baermann ap-

paratus and in press preparations. The heart's blood and other fluids of the body were removed to glass slides with the aid of capillary pipettes, after being diluted with physiologic saline and examined for larvae. Mature worms were obtained from the lumen of the intestine by slitting the wall of this organ in a glass dish containing physiologic saline and removing the worms from the solution as well as from the lining of the intestine.

The Stoll dilution technique was used in making egg counts. The total fecal output for 24 hours of the mice involved in this investigation in no case exceeded 0.22 gms., and usually weighed about 0.2 gms.; in a few cases the weight was as low as 0.05 gms. In making fecal dilutions for the counts, practically the entire fecal sample was used in nearly all cases. For the purpose of ascertaining the presence of eggs, the salt flotation technique was used.

PREPARASITIC DEVELOPMENT

The segmented eggs eliminated with the feces of infested mice hatched in about 24 hours in laboratory cultures maintained at a temperature of 24°C. The newly hatched larva feeds almost continuously and grows considerably during the feeding period which lasts about 4 days during the summer months. The molting larva is encased in a sheath, the cuticle of the first-stage larva, which apparently is not discarded in water. On solid culture media, consisting of moist animal charcoal to which mouse feces have been added, the sheath is discarded. The exsheathed larva is infective to mice, and is morphologically and physiologically identical with the third-stage larva of other strongyles; as will be shown in connection with its morphology and in the discussion, it should be regarded as corresponding to a third-stage rather than a second-stage larva, on the assumption that the first molt has been suppressed.

EXPERIMENTAL INFECTIONS THROUGH THE MOUTH

Experiment 1. Each of two mice (nos. 1 and 2) was fed 500 infective larvae. Five days after the experimental feeding, the feces of these mice were still free of eggs; 7 days after the experimental feeding a few eggs of *L. musculi* were found in the feces of mouse no. 1 and numerous eggs were found in the feces of mouse no. 2.

Experiment 2. Mouse no. 3 was given 6 feedings of 100 larvae each as follows: May 23, 1 P.M.; May 24, 9 A.M.; May 25, 9 A.M., 4 P.M. and 9 P.M.; May 26, 9 A.M. The mouse was killed on May 26,

11:30 A.M., 70½ hours after the initial feeding and 2½ hours after the last feeding. Post-mortem examination for worms yielded the following results:

Thirty-five larvae showing no increase in size and no progress in development beyond those of the infective larvae, were found in the stomach; in the small intestine there were present 143 larvae, some showing no evidence of growth beyond that of the infective larva, others showing an increase in size, and some showing early signs of the first parasitic molt, in addition to 140 preadult worms corresponding morphologically to fourth-stage larvae of other strongyles; of these worms 63 were males and 77 were females. The large intestine contained 9 living infective larvae. The liver, lungs and heart's blood were examined for larvae with negative results.

Experiment 3. Mouse no. 4 was given 2 feedings of 100 larvae each on May 29, 2:30 P.M., and May 31, 2:30 P.M. This mouse died some time between 4:30 P.M., May 31, and 9 A.M., June 1. Post-mortem examination revealed 30 larvae in the stomach showing no evidence of growth beyond that attained by the infective larvae, 80 worms in the small intestine, of which 49 (18 males and 31 females) were in the preadult stage and 31 were in the infective stage. No larvae were found in the liver and lungs.

Experiment 4. Mouse no. 5 was given 200 infective larvae on June 2. On June 7, 5 days after experimental feeding, this mouse was killed and examined for evidence of infestation with the following results:

The small intestine contained 32 worms of which 22 (15 males and 7 females) were in the preadult stage, but were already in the third or final ecdysis, while the remaining 10 worms (6 males and 4 females) were in the final, or adult, stage, having discarded the sheath of the last molt before the host animal was killed. The females did not as yet contain eggs in the uteri. No worms were found elsewhere in the alimentary canal. The lungs were free of worms.

It is evident from these data that the entry of *Longistriata musculi* larvae through the oral route not only leads to the development of these worms to fertile maturity, as evidenced by the appearance of eggs in the feces of the experimental host animal on the seventh day following the administration of the larvae (experiment 1), but that the entire development takes place in the small intestine, as shown in experiments 2, 3 and 4. All the developmental stages, beginning with those indistinguishable from the infective stage, through the various growth changes in that stage, the first parasitic ecdysis, the preadult

stage, which follows the casting off of the sheath, growth changes during the preadult stage, the second parasitic ecdysis, and adult or final stage which follows the final exsheathing, were found in the small intestine. No evidence was found of a migration of the larvae from the alimentary canal to the liver or lungs. *Longistriata musculi* is, therefore, capable of achieving its full development in the intestine following the ingestion of the infective larvae. The latter reach the stomach first, and in this organ some of them, and perhaps all of them, linger for a while and then pass into the small intestine where sexual maturity is attained following growth and development accompanied by 2 molts. Preadult worms were already present in experimentally infected mice about 48 hours after experimental feeding, and adult worms, not yet fully grown, were found 5 days after experimental feeding. The entire parasitic development, commencing with the ingestion of infective larvae and ending in egg-laying maturity, was completed in 7 days.

EXPERIMENTAL INFECTIONS THROUGH THE SKIN

Mice were exposed to experimental infections through the skin with a view to (1) determining whether the skin is a suitable portal of entry of *Longistriata musculi* larvae into the body of the rodent host; (2) tracing the course of migration of the parasites from the skin to the small intestine; and (3) ascertaining the precise locations in the body where the development of the larvae is resumed after being suspended following the preparasitic molt. The results of experimental percutaneous infections involving 17 mice, examined at various intervals following the exposure of the skin to infective larvae, the intervals ranging from ½ hour to 7 days after infection and corresponding to the periods during which migration, growth and development take place, are summarized in table 1.

An examination of the data presented in table 1 shows among other things (1) that the larvae which were placed on the intact skin actually penetrated this tissue and that some of them were still present in the skin layers 4 hours after having been placed on the surface; (2) that at least one larva was found in the stomach as early as one hour after the exposure of the skin to larvae and that fairly large numbers of larvae were found in the stomach 3, 4½ and 6 hours, respectively, following the placing of the larvae on the skin; (3) that the larvae were found in the stomach before they were seen in the small intestine or that many more were present in the stomach than in the small intestine up to 6 hours following skin infection; (4) that

some larvae reached the small intestine as early as 3 hours after they had been placed on the skin and that 10 hours after skin exposure the number of larvae which were present in the intestine was in excess of those present in the stomach; (5) that 24 hours following exposure of the skin to larvae, the latter were localized exclusively in the small intestine, in which organ they continued their development; (6) that preadult worms were present in the intestine about 48 hours

TABLE 1.—RESULTS OF PERCUTANEOUS INFECTIONS OF 17 MICE

Mouse Number	No. of larvae placed on skin	Duration of experiment	Post-mortem results[a]
6	150	1 hour	20 larvae in skin and 1 in stomach; all in infective stage
7	500	2 hours	24 larvae in skin
8	800[c]	1–3 hours	26 larvae in stomach and 5 in intestine; all in infective stage
9	600[b]	½–3½ hours	22 larvae in skin; all in infective stage
10	800[c]	½–4 hours	1 larva in lungs, 2 in esophagus, 15 in stomach, 7 in intestine; all in infective stage
11	1,000	4 hours	4 larvae in skin; all in infective stage
12	1,000	4 hours	Negative
13	1,000	4½ hours	6 larvae in stomach; all in infective stage
14	1,000	6 hours	76 larvae in stomach; all in infective stage
15	150	10 hours	11 larvae in stomach, 27 in intestine; all in infective stage
16	1,000	10 hours	34 larvae in stomach, 94 larvae in intestine; all in infective stage
17	1,000	24 hours	228 infective larvae
18	1,000	24 hours	109 larvae in intestine; stage not noted
19	1,000	48 hours	103 preadult worms in intestine
20	1,000	72 hours	72 preadult worms in intestine
21	200	120 hours	38 worms in intestine; 11 males and 11 females in final stage, and 9 males and 7 females in preadult stage
22	500	7 days	86 fully developed worms (41 males and 45 females in intestine)

[a] Larvae placed on skin as follows: 400 at 11 A.M.; 200 at noon; 200 at 1 P.M. Mouse killed at 2 P.M.
[b] Four consecutive infections of 150 larvae each at intervals of one hour. Mouse killed 30 minutes after final exposure to infections.
[c] Four consecutive infections of 200 larvae each at one-hour intervals. Mouse killed 30 minutes after final exposure to infection.

after skin exposure; (7) and that 5 days after experimental infection the majority of the worms were already in the final (adult) stage, and that 7 days after infection all the worms present in the intestine had attained the adult stage.

Although the data on mouse no. 10 appear to indicate that the path followed by the larvae from the skin to the intestine was the route usually followed by skin-penetrating nematodes, namely from skin to the lungs by way of the circulation and from the lungs to the intestine by upward migration in the bronchioles, bronchi and trachea, and thence back to the alimentary canal, the post-mortem data on the re-

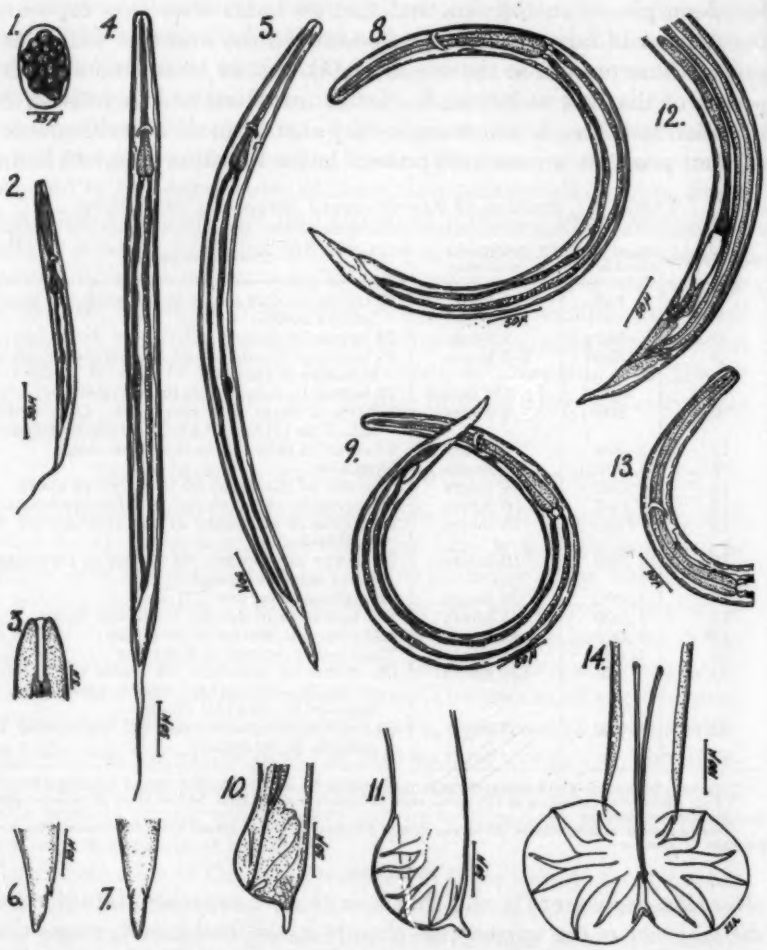


Fig. 1–14.—Stages in the development of *Longistriata musculi*. Fig. 1.—Egg from fresh feces. Fig. 2.—Newly hatched larva. Fig. 3.—Anterior end of preinfective larva. Fig. 4.—Preinfective molting larva. Fig. 5.—Infective larva. Fig. 6.—Tail of infective larva (lateral view). Fig. 7.—Tail of infective larva (ventral view). Fig. 8.—Male larva showing the beginning of the first parasitic molt. Fig. 9.—Female larva showing the beginning of the first parasitic molt. Fig. 10.—Posterior portion of preadult male, 3 days after experimental infection. Fig. 11.—Posterior portion of preadult male in the final molt, 5 days after experimental infection. Fig. 12.—Posterior portion of preadult female. Fig. 13.—Anterior portion of preadult male. Fig. 14.—Bursa of young adult male, 5 days after experimental infection.

maining mice given in table 1 do not support this assumption, despite the evidence that the larvae reached the stomach before they appeared in the intestine in some of the experimental infections. Careful examination of the hearts' blood, the fluid of the peritoneal and thoracic cavities, the lymph glands, lungs, liver, spleen, pancreas, kidneys, and other organs and tissues in which larvae might be present if they were carried in the circulation, yielded consistently negative results in all cases in which such examinations were made, and practically all the mice involved in this investigation were examined with a view to determining the probable path of migration. Aside from this negative helminthological evidence, no lesions suggestive of lung invasion by nematode larvae were noted in any of the mice involved in this investigation. There was a complete absence of petechial and ecchymotic spots in the lungs, lesions usually associated with the invasion of the lungs by nematode larvae.

While the possibility of a direct migration to the alimentary canal through the tissues and cavities of the body must be considered as an alternative to migration through the lungs, the available evidence, especially the failure to find larvae in press preparations of the wall of the stomach and small intestine, lends no support to this possible migratory route. The question of the path followed by the larvae of *Longistriata* from the skin to the alimentary canal must be left open for the time being.

MORPHOLOGICAL ASPECTS OF DEVELOPMENT

The outstanding morphological features in the development of *L. musculi* are shown in the illustrations (figs. 1–14). The brief descriptions which follow help to clarify the illustrations.

Egg.—The egg (fig. 1) has a morphology characteristic of other trichostrongyle eggs; it is 61 to 68μ long by about 38μ wide, elliptical in shape, thin shelled, and segmented when found in fairly fresh feces.

Preinfective larva.—This larva (fig. 2) resembles those of other members of the family Trichostrongylidae. It is slender, cylindrical, tapering slightly anteriorly and more so posteriorly, and is provided with a long filamentous tail. The newly hatched larva is from about 296 to 311μ long by 17μ wide. The mouth opening leads into a cylindrical buccal cavity or pharynx (fig. 3) about 15μ long; the esophagus is characteristically rhabditiform, 91 to 95μ long, its bulb being provided with the usual Y-shaped valve; the intestine, about 120μ long is followed by a short rectum. The nerve ring is about 65 to 79μ, and

the genital primordium 152 to 167μ, respectively, from the anterior extremity. The tail is 60 to 68μ long.

The first preinfective larva grows considerably, attaining a length of 750μ, including the long filamentous tail. At this stage the larva is already ensheathed (fig. 4), the sheath inclosing a short-tailed infective larva.

Infective larva.—Though the infective larva undergoes only one molt, it must be considered as the homologue of the third-stage infective larva of other Trichostrongylidae since it presents morphological features typical of third-stage larvae. In the life cycle of *L. musculi* the molt corresponding to the first molt of other strongyles is evidently suppressed, the molt which takes place being the homologue of the usual second molt since it gives rise to an infective larva.

The infective larva (fig. 5) has the general features of the first-stage larva, differing from the latter principally in the structure of the esophagus and the shape of the tail. It is 610 to 677μ long and 26μ wide. The mouth is closed and leads into a buccal cavity or pharynx about 8μ long, which in turn communicates with a club-shaped esophagus about 163 to 171μ long; the intestine, about 425μ long, is followed by a rectum about 38μ long. The nerve ring, excretory pore and genital primordium are 110μ, 121 to 129μ, and 350 to 587μ, respectively, from the anterior extremity. The tail (figs. 6 and 7) is relatively short and blunt, from 47 to 57μ long, and is provided with two subventral processes located about 10μ from its tip.

Growth of infective larva in host.—In the intestine of the host the third-stage larva increases gradually in length and in width, attaining a size of 750μ by 34μ about 24 hours after experimental infection. Evidence of the first parasitic molt was found in two larvae 725μ long by 26μ wide and 750μ long by 34μ wide, respectively, the smaller worm (fig. 8) being recognizable as a male and the larger worm (fig. 9) as a female, by the respective positions of the genital primordia, that of the female having migrated posteriorly. In the preadult stage the vulva and vagina are seen in the relative position taken up by this genital primordium.

Preadult stage.—The larvae grow considerably during this stage, and show unmistakable sex differentiation. The anterior portion of the larva (fig. 13) shows a small provisional buccal capsule and a cuticular inflation around the head extending to a distance of about 25μ posteriorly. The posterior portion of the male (fig. 10) is distended; the swollen portion forms the bursa and the indistinct folds are the precursors of the bursal rays. In the female (fig. 12) the vulva

and other accessory parts of the reproductive system, as well as the ovary, are well developed about 3 days after experimental infection. At this time the males are 1.38 to slightly over 2 mm. long by 40 to 77μ wide in the swollen posterior portion, and the females are 1.8 to 2.35 mm. long by 50 to 75μ wide. Five days after experimental infection, the preadult worms, already showing evidence of the last ecdysis, are about 3.2 to 3.4 mm. long by 78 to 83μ wide. The rays of the male bursa are fully developed in the worms undergoing the final molt (fig. 11). In a small series of measurements involving only 2 worms of each sex, the males were 3.11 to 3.4 mm. long by 78 to 93μ wide and the females were 3.2 mm. long by 76 to 83μ wide.

Young adult stage.—In young fifth-stage worms, 5 days after experimental infection, the largest females measured 5.1 mm., whereas the largest males were only 4.1 mm. long. In the male at this stage (fig. 14) the bursa and spicules have the characteristic morphology of those of the fully developed adult worm.

DISCUSSION OF LIFE HISTORY

The life history of *Longistriata musculi* presents several interesting features in its development, namely, (1) a deviation from the usual four molts which characterize the development of nematodes generally; (2) the adaptation of the infective larvae to entrance into the host through the mouth and through the skin, either avenue of infection leading to development of the worms to fertile maturity; (3) the migratory course of the larvae following skin penetration, in which the usual route through the lungs is apparently followed only exceptionally; (4) the speed with which the infective larvae reach the stomach and intestine following percutaneous infection; and (5) the failure of the larvae to undergo any evident extraintestinal development following percutaneous infection.

With regard to the number of molts involved in the life history of *L. musculi*, this case is paralleled by the development of *Nippostrongylus muris* as determined by Yokogawa (7). The latter species molts only once during its free-living existence, and the larva is infective to rats after discarding its sheath. Yokogawa regarded the infective larva of *N. muris* as a second-stage larva and considered the development of the worm in the lungs as involving 2 stages, though only one molt was present. Following the first parasitic molt in the lungs, Yokogawa regarded the exsheathed larvae as fourth-stage larvae, a view which fits their morphological status. As already indicated, the writers disagree with Yokogawa's interpretation of the

morphological status of the infective larvae and with his assumption that the growth in the lungs which culminates in a molt involves two stages, one molt being suppressed and, instead, regard the infective larva of *N. muris* as well as that of *L. musculi* as morphologically and physiologically identical with other third-stage strongyle larvae. The morphological identity is evident from the structure of the esophagus which is club-shaped and lacks a masticatory apparatus, in contrast to the rhabditiform esophagus containing a masticatory apparatus which is characteristic of second-stage as well as first-stage strongyle larvae. Moreover, the mouth of third-stage strongyle larvae is closed, whereas in the first and second stages the mouth is open. In this respect, too, the two species under consideration agree with third-stage rather than with second-stage larvae. In addition to the facts already cited, the time which elapses between the hatching of the larvae and the attainment of the infective stage, 4 days in the case of *L. musculi* and 4 to 5 days in the case of *N. muris*, lends additional support to the view that one molt has been suppressed. Under favorable conditions, strongyle larvae molt about 2 days after hatching and molt again two or three days later, the entire preparasitic development being completed in about 4 to 5 days.

From the viewpoint of their behavior, the exsheathed free-living larvae of *N. muris* and of *L. musculi* show the characteristic habits of third-stage larvae. The exsheathed larvae of both forms migrate upwards in culture dishes and bottles and are capable of infecting susceptible hosts, behavior features not exhibited by any known second-stage strongyle larvae. In the opinion of the writers, the preparasitic development of *N. muris* and *L. musculi*, which culminates in a molt, corresponds to the preparasitic development of other strongyles, the first molt being suppressed; the single ecdysis which takes place corresponds to the second molt of other strongyles. It is perhaps significant that the only two species of strongyles of which the free-living development involves only one molt, so far as known at present, are rather closely related and belong to the family Heligmosomidae. It is possible that the suppression of the first molt may be found to be a common feature in the life history of the members of this family.

Since the various stages in the development of nematodes after hatching are separated by molts, the infective larvae of *Longistriata* and *Nippostrongylus* are actually second-stage larvae having a morphology characteristic of third-stage strongyle larvae. However, in order to avoid the designation "third-stage larva" for a worm which has molted only once, the writers propose the following terms for the

stages in the development of strongyles after hatching: First preinfective larva; second preinfective larva; infective larva; preadult; adult. In the two species under discussion, the first two stages are not separated by a molt and only four stages appear after hatching, namely, (1) preinfective larva, (2) infective larva, (3) preadult, and (4) adult. The proposed designations, which have been used in this paper, have the additional advantage of eliminating the term "fourth-stage larva" for a stage in development which can no longer be regarded as larval, since sex differentiation is not only well established but is readily apparent even on superficial examination.

It is quite evident, in view of the rather ample data available on the post-mortem findings in mice at various intervals following percutaneous infection, that the larvae of *L. musculi* become arrested in the lungs only exceptionally even if they do migrate through the respiratory tract. This, as well as the probability of a more direct course of migration to the alimentary canal, accounts for the exceptionally rapid appearance of the larvae in the stomach and intestine following skin penetration. As is well known, the migratory course of various species of hookworms following percutaneous infection is from the skin to the lungs and results in a considerable delay of the larvae in these organs. The boring of the larvae through the pulmonary capillaries, their migration into and from the alveoli, along the ramifying bronchioles, up the bronchi and the trachea and thence into the esophagus, is evidently time consuming and accounts for the relatively long interval elapsing between the penetration of the larvae into the skin and their arrival in the intestine.

The essential facts in the development of *L. musculi* following the entry of the larvae through the skin are in striking contrast to those observed by Yokogawa and others with reference to the development of *N. muris*. The infective larvae of the latter species develop in the lungs, molt there, and enter the intestine as preadults. In fact the writers (4) have shown that infective larvae of *N. muris* are incapable of surviving in the digestive tract of rats, and if they fail to reach the lungs after being swallowed, they pass into the large intestine where they die and are expelled with the feces. *L. musculi*, on the other hand, undergoes its entire parasitic development in the small intestine regardless of the portal of entry into the body of its host. The ability of the infective larvae of this species to penetrate the skin is not correlated with an extraintestinal developmental phase as it is in the case of *N. muris*. The infective larvae of the latter, as a matter of fact, are not well adapted to utilizing the mouth as a portal of entry into

rats, as shown by Yokogawa (7), Africa (1) and by the writers (5). *Nippostrongylus* is a striking example among strongyles of an almost obligatory skin penetrator, since this avenue of entrance into its hosts leads to the lungs whereas an entry through the mouth results as a rule in only a slight infestation or in a failure of the worms to become established in the host.

COURSE OF INFECTION WITH L. MUSCULI

The course of infection with *L. musculi*, in so far as this can be determined by quantitative studies in the form of counts, made at more or less regular intervals, of the number of worm eggs in definite amounts of the feces of the experimentally infected white mice, was studied in 5 host animals of which 3 were infected percutaneously and 2 through the oral route. Each mouse received an initial dose of 500 larvae, and the 3 mice which were superinfected received a similar second dose. The feces of these mice were examined on the sixth day following experimental infection, with negative results in all cases. Eggs were found by the salt flotation technic on the 7th day and the counts were begun either on that day or the next day.

Figure 15 is a graphic representation of the rise and fall in the egg output of the worms in mice nos. 23, 24 and 25 which were infected through the skin. The graphs show that the peak of egg production in the case of mice nos. 23 and 24 was reached on the 9th day after experimental infection, or 2 days after eggs were first noted in the feces, and that eggs were no longer demonstrable in the feces on the 14th day in case of mouse no. 24 and on the 16th day in the case of mouse no. 23. The two mice were superinfected through the skin 18 days after the first infection.

Mouse no. 23 was kept under observation until it died, 69 days after superinfection. During this period only one egg was discovered in the feces on the 9th day and three eggs on the 15th day after superinfection; these eggs were demonstrated by the salt flotation technique. At necropsy no worms were found in the intestine of this mouse.

Mouse no. 24 began to discharge eggs 7 days after superinfection and was still discharging eggs 41 days after superinfection; two days later this mouse died and post-mortem examination showed 18 gravid females and 13 males in the small intestine.

Mouse no. 25 reached a peak of egg elimination 8 days after experimental infection and showed no eggs in the feces 5 days later. Two days after the mouse became negative it was superinfected

percutaneously. An inspection of the graph shows that the slight egg output from the worms of this mouse, beginning 9 days after superinfection, disappeared after a few days, and that following this no eggs were demonstrable in the feces for 30 days, except once as noted on the graph. This was followed by the reappearance of small numbers of eggs in the feces during a period of 15 days at the end of which, 65 days after superinfection, the mouse died. Post-mortem

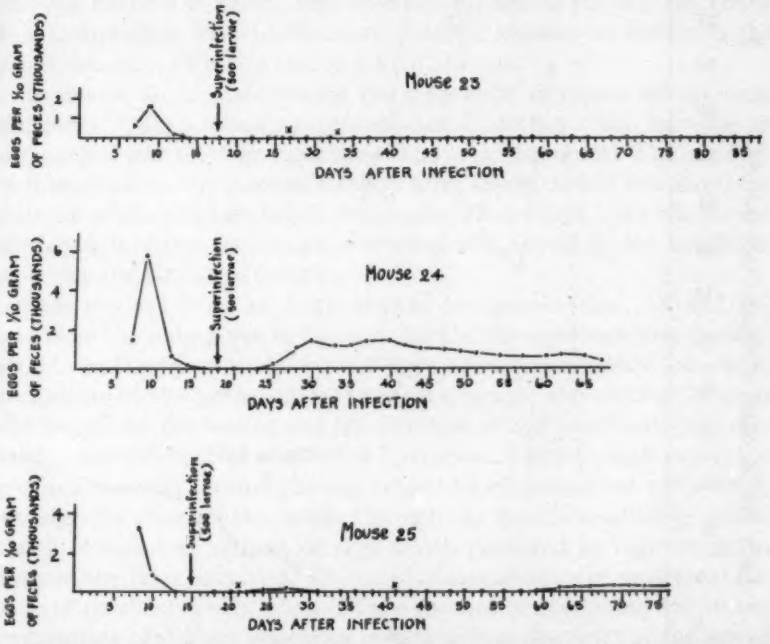


Fig. 15.—Graph of eggs per one-tenth gram of feces of mice nos. 23, 24 and 25, each infected percutaneously with 500 larvae, and superinfected percutaneously with 500 larvae as indicated. x indicates 1 to 3 eggs in total fecal output.

examination showed 22 worms in the intestine, 9 males and 13 gravid females.

From these data it is evident that following percutaneous infection of mice with *L. musculi*, the egg output quickly reached a peak and that this was followed by an equally rapid decline. A superinfection, in so far as available data show, either failed to reestablish egg production, or reestablished egg production at a level lower than that attained during the initial infection. However, the egg output following the second infection, was more stable and persisted for a rela-

tively long time. The egg output of the worms in mouse no. 25, following superinfection, involved a prolonged negative phase between 2 positive phases, due perhaps in part to a delayed development of

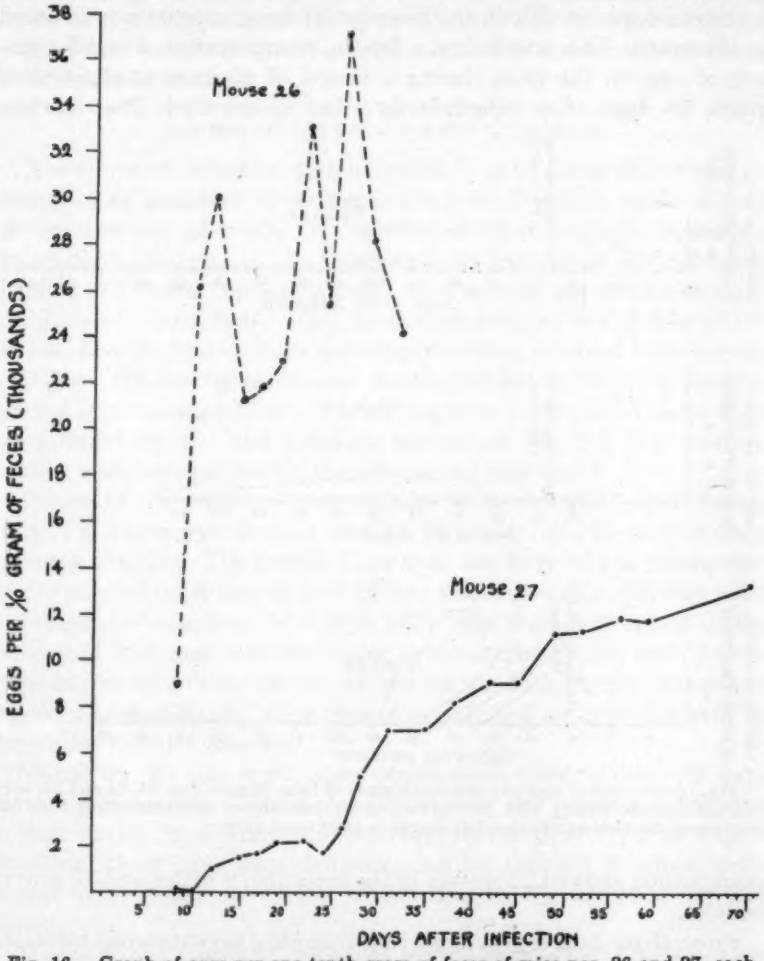


Fig. 16.—Graph of eggs per one-tenth gram of feces of mice nos. 26 and 27, each infected through the mouth with 500 larvae.

some of the worms, similar to the delayed development of *Nippostrongylus muris* following superinfection, as determined by Schwartz, Alicata, and Lucker (5), in 1931, and subsequently confirmed by Chandler (2), Spindler (6), and Graham (3).

The graphs shown in fig. 16 are of the egg output of mice nos. 26 and 27 infected through the mouth. An inspection of these graphs shows not only a tremendously large output of the eggs as compared to that of the mice infected percutaneously, but shows also a prolonged persistence in egg production at high levels. Eggs appeared in the feces of mouse no. 26 seven days after experimental infection and were still being discharged in large numbers 25 days later when the last egg count was made. Two days subsequent to the last egg count this mouse died. Post-mortem examination showed 53 worms in the small intestine, 18 males and 35 gravid females.

In mouse no. 27, infected on the same date as mouse no. 26, eggs appeared 7 days following percutaneous infection. The increase in egg output was more gradual than that in mouse no. 26. Egg production was still on the increase 63 days after experimental infection, the date on which the last count was made. Three days later the mouse died; post-mortem examination showed 103 worms in the intestine, 41 males and 62 gravid females.

It is evident from an inspection of the graphs (figs. 15 and 16) and from the data given in the text, that while eggs were first demonstrable in the feces of the mice 7 days after experimental infection, regardless of the portal of entry of the larvae, the number of eggs discharged by the worms and the duration of egg production are correlated with the portal of entry of the larvae. The percutaneous route resulted in a relatively slight egg output which lasted but a few days, whereas the entry of the larvae through the mouth resulted in a relatively tremendous output of eggs which persisted at high levels as long as the mice survived. The rapid disappearance of eggs from the feces of percutaneously infected mice can not be accounted for on the assumption of slighter infections resulting from the entry of the larvae through the skin, as compared to those resulting from the ingestion of larvae. In a series of experiments involving 5 mice (nos. 28 to 32) infected percutaneously with 300 to 500 larvae, post-mortem worm counts made from 7 to 16 days following infection, yielded 102, 158 and 86 worms, respectively, in the mice given 500 larvae each, and 47 and 55 worms, respectively, in the 2 mice given 300 larvae each, with males and females present in fairly equal numbers in all cases. These figures compare favorably with the number of worms recovered from mice nos. 26 and 27 following infection through the mouth. Assuming, therefore, that the wide discrepancy in the number of eggs produced by the worms following the two avenues of entrance into the host are not due to differences in the percentage of

larvae which actually reached the intestine and developed there to maturity, it is probable that the migration of the larvae from the skin to the intestine, involving a passage through various tissues and cavities, stimulated the defense mechanism of the body. The response to this stimulation is apparently of a sort which interferes with egg production even before the worms die and are eliminated from the intestine. The amazingly low egg output from the worms in mice nos. 24 and 25, despite the presence of 18 and 13 female worms, respectively, in these two animals, as compared to the egg output of the worms in mouse no. 26 which had approximately only twice as many females, or even as compared with the egg output of the worms in mouse no. 27 which harbored 62 females, is certainly suggestive of a host resistance involving among other things inhibition of egg production.

In the case of *N. muris*, the inhibition of development and of egg production has been confirmed by several workers, as already stated, since Schwartz, Alicata and Lucker (5) called attention to this fact. Experimental percutaneous infection of rats with *Nippostrongylus*, as determined by these workers, resulted in most cases in the rapid attainment of a peak in egg production followed, as a rule, by an equally rapid decline. In superinfections, produced following this decline, but few or no eggs were demonstrable in the feces of a large proportion of rats, despite the presence in the intestine of relatively large numbers of worms, including gravid females. The course of infection with *Nippostrongylus* in rats following the invasion by larvae through the skin is similar, as a rule, to the course of infection with *Longistriata* in mice following the same portal of entry. This general similarity in egg production coupled with the same avenue of entrance into the body, suggests that the passage of the larvae of the two species under discussion through the tissues of their respective hosts brings about a defense reaction to the invasion of the parasites which terminates the egg production and, therefore, the multiplicative capacity of the worms, in a few days.

SUMMARY

Under favorable conditions, the eggs of *Longistriata musculi* hatched in about 24 hours after they were eliminated from the host, *Mus musculus*, and the larvae attained their full development in 4 days. Following one preparasitic molt, the larvae were infective to mice.

Although the infective larva has molted only once, its morphology

and behavior are similar to known third-stage trichostrongyle larvae. The view is advanced that the first molt has been suppressed, and the molt which takes place corresponds to the second preparasitic molt of related nematodes. As established by visible molts, it is a second-stage larva, but, as established by morphology and behavior, it is the equivalent of the infective third-stage larva of trichostrongyles in general.

The following designations are proposed in this paper for the stages in the development of strongyles: (1) First preinfective larva; (2) second preinfective larva; (3) infective larva; (4) preadult; and (5) adult. The suppression of one molt during the free-living period reduces the life cycle to 4 stages.

White mice were infected with *Longistriata* through the mouth and through the skin, either portal of entry leading the worms to the small intestine, where they undergo their entire development, accompanied by two molts.

A few hours after percutaneous infection, larvae were found in the stomach and intestine and they became localized in the intestine exclusively 24 hours after having been placed on the skin.

The precise route taken by the larvae from the skin to the intestine has not been determined; evidently, the migratory course usually followed by skin-penetrating nematodes, involving a passage through the lungs, was followed only exceptionally by *L. musculi*, so far as available data show.

Preadult worms, showing unmistakable sex differentiation, were found in the intestine of white mice about 48 hours after experimental infection through the mouth or skin, and final stage worms (adults), not fully grown, were found in these host animals 5 days after entry by either portal.

Regardless of the portal of entry of the larvae, eggs were first noted in the feces of experimentally infected mice 7 days after the administration of larvae.

The period of egg production in 3 white mice infected percutaneously with 500 larvae was limited to approximately two weeks. Superinfection with 500 larvae following the apparent cessation of egg production, yielded practically negative results in one case coupled with absence of worms in the intestine, and resulted in only a small output of eggs in the two remaining mice which harbored worms of both sexes, the egg output being far below the expected output, considering the number of females present.

Following infection with 500 larvae through the mouth, the egg

output from 2 mice reached a far higher level than that attained following percutaneous infection. Moreover, the high level of egg production persisted until the mice died, 32 and 63 days, respectively, following the ingestion of larvae.

It is suggested that the glaring differences in egg production by the worms, the differences correlated with the portal of entry of the larvae into white mice, is probably due to a marked stimulation of the defense mechanism of the host coincident with the migration of the larvae through various tissues following percutaneous infections. This stimulation is either lacking or is not marked following ingestion of larvae.

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

259TH MEETING

The 259th meeting of the ACADEMY was a joint meeting with the Medical Society of the District of Columbia, held in the Auditorium of the New National Museum on Wednesday, November 21, 1934. About two hundred and fifty persons were present. President TUCKERMAN introduced Dr. WILLIAM A. WHITE, Superintendent of St. Elizabeths Hospital, who delivered an address on *The frontier of the mind*, which has been published in full in this JOURNAL **25**: 1–15, 1935.

260TH MEETING

The 260th meeting of the ACADEMY was held in the Assembly Hall of the Cosmos Club, on Thursday, December 20, 1934. About 60 persons were present. President TUCKERMAN called the meeting to order and announced the nature of a series of programs planned for the future before presenting THOMAS R. HENRY of The Evening Star, who spoke upon, *Introducing science to the public*, and AUSTIN H. CLARK of The Smithsonian Institution, who discussed, *Science and the public.*

261ST MEETING

The 261st meeting of the ACADEMY was held in the Assembly Hall of the Cosmos Club on Thursday, January 17, 1935. About sixty-five persons were present.

Doctor ARTHUR L. DAY, director of the Geophysical Laboratory of the Carnegie Institution, delivered an illustrated address on *Public safety in earthquake regions.*

At the close of the address the President declared a recess, and asked the members to remain for the 37th annual meeting of the ACADEMY.

37TH ANNUAL MEETING

The thirty-seventh annual meeting of the ACADEMY was called to order by President TUCKERMAN at 9:15 P.M., January 17, 1935. Thirty-five members were present. The minutes of the 36th annual meeting were read by the recording secretary and approved by vote of the Academy.

The corresponding secretary reported on the membership and activities of the year 1934 as follows: Twenty-eight persons were elected and qualified as regular members. Twenty-two resignations were accepted; twelve of these were resident and ten non-resident members.

The ACADEMY stood in respect as the Secretary read the list of six members lost by death:

J. M. ALDRICH	ARTHUR SCHUSTER
K. F. KELLERMAN	HOMER C. SKEELS
E. W. NELSON	H. D. GIBBS

On January 1, 1935, the membership consisted of 15 honorary members, 3 patrons, and 536 members, one of whom was a life member. The total membership was 554 members, of whom 398 reside in or near the District of Columbia, 133 in other parts of the continental United States, and 23 in foreign countries. The net loss of membership was 1.

The recording secretary's report summarized five public meetings, two of which were joint meetings, one with the Philosophical Society, the other with the Medical Society.

The treasurer's report detailed the financial operations of the ACADEMY with an itemized list of the assets. A summary of the report showed:

Cash balance, January 1, 1934	$1,365.35
Cash receipts to December 31, 1934	5,132.17
Total cash to be accounted for	6,497.52
Total disbursements	3,970.98
Cash balance, December 31, 1934	2,526.54
Investments, cost at time of purchase, total	21,096.37

F. B. SCHEETZ, chairman, read the report of the auditors verifying the operations of the treasurer's office and the assets of the ACADEMY. On motion of C. J. HUMPHREYS, both reports were accepted and ordered filed.

JOHN A. STEVENSON, senior editor, read the report of the Journal which covered the publication of Volume 24, for the year 1934. Volume 24 consisted of 576 pages, including an eight page index. This compares with 588 pages in 1933, 572 in 1932, 552 in 1931; and 520 in 1930. It contained 78 original papers, as contrasted with 77 in 1933, 79 in 1932 and 80 in 1931. Forty-five papers were by members of the Academy, and 33 were communicated, of which latter number it should be noted six were by authors who became members of the ACADEMY following the time of publication of their papers. The original papers were illustrated by 42 line cuts and 27 half tones. Space in the volume was distributed among the different sciences as follows:

	Pages
2 papers on Mathematics	25.3
1 paper on Physical geography	6.5
5 papers on Physics and geophysics	44.3
9 papers on Chemistry, including pharmacology	37.6
3 papers on Geology, including hydrology and petrology	43.5
1 paper on Biology	1.1
15 papers on Paleontology and paleobotany	67.2
14 papers on Botany	109.6
20 papers on Zoology	90.2
5 papers on Ornithology, malacology, entomology	42.9
3 papers on Ethnology and archeology	12.1

Proceedings of the Academy and affiliated societies occupied 53.4 pages, as follows:

The Academy	4.6
Anthropological Society	1.3
Botanical Society	3.9
Geological Society	18.6
Philosophical Society	15.0

Scientific notes and news, and obituaries occupied the remaining 44.1 pages.

The recording secretary read the report of the tellers showing the election of the following officers for 1935: President, G. W. MCCOY; non-resident vice-presidents, W. M. CLARK, E. D. MERRILL; corresponding secretary, PAUL E. HOWE; recording secretary, CHARLES THOM; treasurer, H. G.

AVERS; managers for the term of three years ending January, 1938, R. S. BASSLER, C. A. BROWNE.

The corresponding secretary read the nominations for resident vice-presidents representing the affiliated societies, as follows:

Philosophical Society of Washington, O. H. GISH
Anthropological Society of Washington, MATTHEW W. STIRLING
Biological Society of Washington, CHAS. E. CHAMBLISS
Chemical Society of Washington, J. F. COUCH
Entomological Society of Washington, HAROLD MORRISON
National Geographic Society, F. V. COVILLE
Geological Society of Washington, H. G. FERGUSON
Medical Society of the District of Columbia, HENRY C. MACATEE
Columbia Historical Society, ALLEN C. CLARK
Botanical Society of Washington, NATHAN R. SMITH
Archaeological Society of Washington, WALTER HOUGH
Society of American Foresters (Washington Section), S. B. DETWILER
Washington Society of Engineers, PAUL C. WHITNEY
American Institute of Electrical Engineers (Washington Section), HERBERT G. DORSEY
American Society of Mechanical Engineers (Washington Section), HERBERT N. EATON
Helminthological Society of Washington, G. STEINER
Society of American Bacteriologists (Washington Section), H. W. SCHOENING
Society of American Military Engineers (Washington Post), C. H. BIRDSEYE
Institute of Radio Engineers (Washington Section), J. H. DELLINGER

On motion, the recording secretary was instructed to cast the vote of the Academy for the nominees, and they were declared elected.

President TUCKERMAN appointed past presidents WETMORE and ADAMS to escort Dr. MCCOY to the Chair. President MCCOY made a brief address and declared the meeting adjourned.

CHARLES THOM, *Recording Secretary*

ANTHROPOLOGICAL SOCIETY

The Anthropological Society of Washington at its annual meeting held on January 15, 1935, elected the following officers for the ensuing year: *President*, MATTHEW W. STIRLING; *Vice-president*, FRANK H. H. ROBERTS, JR.; *Secretary*, FRANK M. SETZLER; *Treasurer*, HENRY B. COLLINS, JR.; *Vice-President of the Washington Academy of Sciences*, MATTHEW W. STIRLING; *Members of the Board of Managers*, C. W. BISHOP, G. S. DUNCAN, H. W. KRIEGER, T. D. STEWART, W. D. STRONG.

A report of the membership and activities of the Society since the annual meeting held on January 16, 1934 follows:

Membership:

Life members	3
Active members	45
Associate members	8
Honorary members	18
Corresponding members	18
Total:	92

Deceased:	
Active members	1
New Members:	
Active members	1
Associate members	1
Total:	2

The Society lost through death one of the oldest and most devoted active members, Mr. FELIX NEUMANN, February 7, 1934.

Members elected during the year were: Dr. W. M. COBB and Mr. W. J. WINTER.

The financial statement (Treasurer's report) is as follows:

Funds invested in Perpetual Building Ass'n	$1170.43	
21 shares Washington Sanitary Improvement Co., par value $10 per share	210.00	
2 shares Washington Sanitary Housing Co., par value $100 per share	200.00	
Cash in bank	228.37	
Total	$1808.80	
Bills outstanding:		
To American Anthropological Ass'n	$50.00	
To Printer	3.75	
Total	53.75	53.75
Net Balance		$1755.05

Papers presented before the regular meetings of the Society were as follows:

January 16, 1934, 649th regular meeting, *Indian food plants and their historical significance*, by W. T. SWINGLE, Bureau of Plant Industry, U. S. Department of Agriculture.

February 20, 1934, 650th regular meeting, *The historical implications of Some Algonquian Studies*, by T. Michelson, ethnologist, Bureau of American Ethnology.

March 20, 1934, 651st regular meeting, *Future problems in anthropology*, by A. HRDLICKA, curator of physical anthropology, U. S. National Museum.

April 17, 1934, 652nd regular meeting, *Some laws of the early Iroquois league*, by President J. N. B. Hewitt, ethnologist, Bureau of American Ethnology, who gave his retiring address.

October 16, 1934, 653rd regular meeting, *Louisiana relatives of the Ohio* mound builders, by F. M. SETZLER, assistant curator, Division of Archeology, U. S. National Museum.

November 20, 1934, 654th regular meeting, *Archeological explorations in northeastern Honduras*, by W. D. STRONG, archeologist, Bureau of American Ethnology.

December 18, 1934, 655th regular meeting, *How the northern Indian hunts*, by J. M. COOPER, Catholic University of America.

All regular meetings, except the 651st, were held in Room 43 of the U. S. National Museum.

FRANK M. SETZLER, *Secretary.*

SCIENTIFIC NOTES AND NEWS

Prepared by Science Service

NOTES

The Great Drought of 1934.—Just how bad the Great Drought of 1934 was, has been made the subject of a special study by meteorologists of the U. S. Weather Bureau. All sections of the country, except along the Atlantic coast, the east Gulf area, and the Pacific Northwest, had below normal rainfall and much of the country had either the lowest of record or the total for the year approximated the previous low, Mr. KINCER states. Colorado, Indiana, North Dakota, Ohio, and South Dakota had the least annual rainfall of record, while Kansas, Montana, Nebraska, New Mexico, Utah, and Wyoming had only about one inch more than their previous low record. Thus approximately one-fourth of the States had in 1934 either the least precipitation of record or the annual totals approximated the previous low. Only one-third of the States had as much as normal. Almost as important as the rainfall in producing unfavorable weather effects were the high temperatures, especially during the growing season, which made less effective the rain that did occur. It was an abnormally warm year everywhere, except locally in the Northeast. A large northwestern area had the warmest year of record with some localities showing an accumulated excess of temperature as great as 2,000 degrees, or an average daily excess of nearly 6 degrees.

U. S. Public Health Service.—A sharp outbreak of cerebrospinal meningitis, fortunately not long-lived, occurred in the F.E.R.A. transient camps in Washington and Fort Eustis, Va., early in February. Hygienic and quarantine measures recommended by officers of the U. S. Public Health Service were put into effect and brought the epidemic under control.

Experiments by Dr. CHARLES ARMSTRONG of the National Institute of Health have shown that mice can be made resistant to encephalitis of the *St. Louis 1933* type by dropping into their noses, at seven-day intervals, a three per cent solution of sodium alum. This experimental work, he states, "suggests lines of study which may possibly lead to the development of procedures of practical value in preventing infections contracted by way of the nasal mucous membranes."

Legislation for the promotion of national economic security, now pending before Congress, provides for $10,000,000 to be expended in public health work, of which $2,000,000 is earmarked for basic research.

Geological Survey.—Continuing the series of brief reports being sent to State Geologists, there has been transmitted an article on the copper and iron deposits of Virginia, describing recent work under a Public Works allotment. These deposits have been mined intermittently for at least 150 years. First the rich oxidized iron ores were smelted in crude furnaces. Later, methods of iron production improved until a generation or two ago Virginia was one of the leading producers of iron. Concomitantly with the increased iron output, the rich copper ores at water-level were exploited. Now practically all that remains are the original masses of iron sulphide, carrying inconsequential amounts of gold and copper, but these form a large potential reserve of raw material suitable for the manufacture of sulphuric acid.

National Bureau of Standards.—Dr. L. B. TUCKERMAN of the mechanics

and sound division has been asked to deliver the Edgar Marburg Lecture for 1935 at the annual meeting of the American Society for Testing Materials in Detroit next June.

Dr. W. W. COBLENTZ embarked on January 31 for a month's stay in Porto Rico where he is to advise at their school of tropical medicine on methods and equipment for measuring the solar ultra violet radiation useful in therapeutics. He will also carry on personal research on the measurement of the solar ultra violet radiation at this tropical station.

Children's Bureau U. S. Department of Labor.—The rickets studies carried on by the United States Children's Bureau in collaboration with the Pediatric and Surgical Departments of the Yale School of Medicine, have included a clinical investigation of the relation of rickets to defective formation of teeth and to the occurrence of dental caries, the results of which have been described by MARTHA M. ELIOT, M.D. and SUSAN P. SOUTHER, M.D., of the Children's Bureau, and BERT G. ANDERSON, D.D.S. and SUMTER S. ARNIM, D.D.S., of New Haven. The data assembled in this study indicate that enamel hypoplasia of the permanent teeth, especially the type characterized by a symmetrical distribution of defects in those teeth which are forming during infancy and early childhood, is frequently associated with rickets; that the more severe the rachitic process the more frequently do hypoplastic defects develop; and that, conversely, when severe hypoplasia was found, a definite history of moderate or severe rickets was established in nearly all cases by roentgenologic evidence. Dental caries too was found more often in children with a known history of rickets. Howtory, since caries appeared more often in teeth with hypoplastic defects than in those with none, it is possible that the latter relationship may account for the former. The data showed that children who have had several of the severe infectious diseases of childhood (including pneumonia and bronchitis) tend to have defects in the enamel more often than children who have had fewer of these diseases.

U. S. National Park Service.—There appears to be a definite move on the part of interested organizations and individuals to change the status of the Olympic National Monument to that of a national park, and with this possibility in view the National Park Service is carrying on some careful surveys in the area in order to have a full knowledge of the Olympic elk and its migrations before attempting to define boundary lines.

Smithsonian Institution.—The National Zoological Park will receive substantial additions and improvements to its housing accommodations through an allotment of $680,000 of PWA funds announced January 16 by Secretary of the Interior ICKES. Contemplated changes thus far announced by Director WM. M. MANN include an addition to the bird house, a new elephant house, and a house for the small mammals, with special accommodations for the apes. The elephant house and pens will be turned over to the hippopotamus and the rhinoceros, at present in rather limited quarters. To meet an urgent need of the Zoological Park, a machine shop will also be built.

Evidence that the practice of sacrificing a woman before going on the warpath was a widespread practice among North American tribes has been uncovered by Dr. TRUMAN MICHELSON of the Bureau of American Ethnology. He has found traces of this custom in the literature relating to the

Ojibwas and Hurons. Hitherto it was supposed to have been confined to the Pawnee.

New specimens of piranha, the *Brazilian man-eating fish* of the natural history books, have been added to the National Museum collections by B. A. KRUKOFF.

Carnegie Institution of Washington.—The moon's mountainous surface will be used as an astronomical *yardstick* by Dr. EDISON PETTIT and members of the astronomical staff of the Mount Wilson Observatory, in an endeavor to obtain information about the surface of the planet Mercury. The percentage of radiant heat in total reflected radiation from the moon's surface varies with the lunar phases, it has been found. Radiological observations will be made on Mercury as it passes through its phases, and this recently acquired knowledge about the moon will be applied to the data thus obtained.

Important scientific messages from the Watheroo Magnetic Observatory in Western Australia to the Department of Terrestrial Magnetism are transmitted through radio station VK5HG in Southern Australia to amateur stations in the eastern United States whence they are received by the Department.

Dr. G. R. WAIT, of the Department of Terrestrial Magnetism, by invitation attended the 41st annual meeting of the American Society of Heating and Ventilating Engineers at Buffalo, New York, January 27–30, 1935, where he presented a paper on *Large-ion and small-ion content of air in occupied rooms* by himself and O. W. TORRESON.

Volcanoes in Central America are the objective of a two-man expedition from the Geophysical Laboratory, now in the field. The two volcanologists, Dr. J. W. GREIG and Dr. E. G. ZIES, expect to spend about three months in Salvador and Guatemala.

Dr. ALBERT F. BLAKESLEE, Acting Director of the Department of Genetics of the Carnegie Institution of Washington, located at Cold Spring Harbor, Long Island, was elected on January 28 a corresponding member of the Academy of Sciences of the Institute of France.

Helminthological Society of Washington.—The Proceedings of the Helminthological Society of Washington are now being published as a separate journal. It is devoted to the publication of notes and papers in helminthology and related fields and includes parasites of both plant and animal hosts. Those interested either as contributors or subscribers should communicate with the editor, JESSE R. CHRISTIE, Bureau of Plant Industry, U. S. Dept. of Agriculture, Washington, D.C.

Pan-American Union.—The meeting held February 10 by the Washington Chapter of the Pan-American Medical Association at the Legation of Panama was devoted to intestinal surgery. A meeting is being planned for March in Georgetown University in honor of Col. B. K. ASHFORD, who discovered that the so-called tropical anemia in Puerto Rico was really caused by hookworms, thus laying down the basis for a worldwide campaign against the disease. The officers of the Chapter are Dr. HENRI DEBAYLE, Charge d'Affaires of Nicaragua, president, Surg. Gen. ROBERT U. PATTERSON, vice-president, and Dr. A. A. MOLL, scientific editor of the Pan-American Sanitary Bureau, secretary.

Society of American Foresters.—The Society of American Foresters held its thirty-fourth annual meeting in Washington, January 28, 29, and 30. The afternoon session of Wednesday, January 30, was devoted to a symposium on forest fire control in the coastal plains section of the South. Participating were: A. B. HASTINGS, E. L. DEMMON, W. G. WAHLENBERG, S. W. GREENE, I. F. ELDREDGE, H. L. STODDARD and CHAUCEY KUEHN. It was developed that scientific observations, mostly under control conditions where comparison with like unburned areas is possible, have shown that within reason fire is a good thing for longleaf pine. This species is fire-resistant in all except its first few months of life, because of its thick bark and its trick of protecting its all-important *leader* bud with a dense bundle of leaves. Fire kills less valued competing pines and hardwood species, and lets the young longleaf trees grow.

Fire, it has also been found, helps the longleaf seedlings against one of the most serious of pine diseases, the brown spot of their leaves. In one experimental area, young pines kept wholly protected from fire showed twice as much of this infection as did trees of similar age that stood on ground regularly burned over.

Fire appears also to be beneficial to the soil itself, and to the grass that grows among the trees, and thus to the cattle that eat the grass. Unburned areas, to be sure, did have soil somewhat more porous that that in burned areas; but this advantage was offset by the better chemical condition of the burned-over soil. Burned-over soil produced twice as much green weight of vegetation, which was also of better nutritive quality than the plants from unburned areas. And cattle grazed in burned-over woods gained more weight and were sleeker-looking than comparison herds kept in fire-free woods.

The common practice of burning the woods every spring is too much. Much less frequent use of fire is calculated to bring better results, in all probability. Tests of just how often the red demon can be invoked with benefit rather than harm are now in prospect.

NEWS BRIEFS

Wild ducks are scarce in Mexico, no less than in this country. Investigators of the U. S. Biological Survey, who are studying certain duck species that nest in the United States and Canada and winter in Mexico, have learned from Mexican sportsmen, as well as from their own observations, that the serious duck shortage felt for some years in this country has its close reflection in our next-door neighbor on the south.

Four thousand acres of forest still in completely primeval condition, in the northwest part of Pennsylvania, have been acquired by the U. S. Forest Service and will be kept as a primitive area. The forest, known as the Tionesta tract, consists of a mixed stand of hardwoods and hemlocks. The tract is of historic as well as scientific interest, for it is the last uncut, unburned remnant of the wilderness that gave the colony founded by William Penn the name *Penn's Woods*—Pennsylvania.

Obituary

HARRY DRAKE GIBBS, consulting chemist, died December 28, 1934, after a brief illness, at Hyattsville, Maryland. He was born March 10, 1872, at Cincinnati, Ohio, and received his technical education at Rose Polytechnic Institute and Cornell University, obtaining the degree B.S. from the latter institution. Stanford University granted him the Ph.D. degree in 1913. He was assistant professor of chemistry, Oregon Agricultural College, 1901–3; research assistant, Stanford University 1904–5; chief chemist of the San Francisco Board of Health, 1905–7. The years 1907–14 were spent in the Philippine Islands where he held a series of important positions including chief, Food and Drug Inspection Laboratory; chief, Department of Chemistry, University of the Philippines; assistant to the director, Bureau of Science; and finally head of the Food and Drug Board of the Islands. Coming to Washington in 1914 as assistant chief, Eastern Food and Drug Inspection District, he became in 1915 chemist in charge of the Color Laboratory of the Bureau of Chemistry. During the war he served as head of the Division of Chemical Technology and Industrial Relations of the National Research Council. At this time he was also head of the Chemical Section of the Department of Science and Research, Bureau of Aircraft Production. Following the war he was research chemist, E. I. du Pont de Nemours & Co., 1919–22; senior chemist, National Institute of Health, 1922–29; and finally consulting chemist, 1929–34. In addition to the Washington Academy of Sciences, Doctor Gibbs was a member of the Philippine Islands Medical Association, American Chemical Society, Deutsche Chemische Gesellschaft, A.A.A.S., Delta Tau Delta and Sigma Xi. He was the author of numerous publications in his chosen field and the holder of a number of patents on chemical processes.

CHARLES DAVID WHITE, of the U. S. Geological Survey, died at his home, 2812 Adams Mill Road, Washington, D. C., February 7, 1935. He was born at Palmyra, N. Y., July 1, 1862, and received the B.S. degree from Cornell University in 1886, that same year joining the U. S. Geological Survey as assistant paleontologist. From that grade he advanced steadily to chief geologist in 1912, a position he filled until 1922. His latest title was that of principal geologist. Doctor White's early work was concerned with the fossil plants from the Cretaceous sediments occurring on the coastal plain from Virginia to Marthas Vineyard Island, but most of his life's work was concentrated on the paleobotanic, stratigraphic, and genetic problems connected with the origin and occurrence of coal and petroleum. Numerous papers on these subjects bear witness to his industry and productivity. At the time of his death he was engaged in an extensive study of the coal floras of Illinois and Oklahoma. Doctor White was honorary curator of fossil plants at the U. S. National Museum; research associate of the Carnegie Institution; and a member of many scientific societies, including the National Academy, American Philosophical Society, Geological Society of America, the American Association for the Advancement of Science, and the Washington Academy of Sciences. He was honored with the Sc.D. degree from the University of Rochester in 1923 and from Williams College in 1925. One of his recent awards was the Walcott medal in April, 1934, for his investigations of primitive life in early geologic strata.